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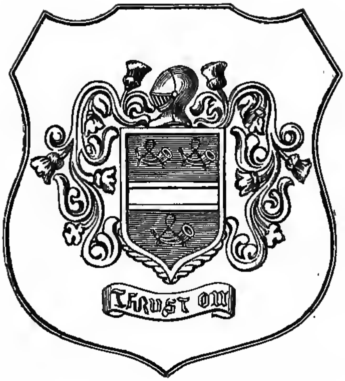

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THE

# FOULING AND CORROSION

OF

# IRON SHIPS:

THEIR

## CAUSES AND MEANS OF PREVENTION,

WITH

## THE MODE OF APPLICATION TO THE EXISTING IRON-CLADS.

BY

rederick

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"THE ECONOMY OF STEAM POWER ON COMMON ROADS;" "THE BEST MODE OF PROTECTING LONDON FROM THE RAVAGES OF FIRE;" "FIRES, FIRE ENGINES, AND FIRE BRIGADES," ETC.

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1867.

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"That which is perfectly obvious to any man of common sense, so soon as it is mentioned, may, nevertheless, fail to occur even to men of considerable ingenuity."—*Whately*

TO

THE RIGHT HONORABLE

SIR JOHN PAKINGTON, BART., G.C.B., D.C.L., M.P.,

PRESIDENT OF THE INSTITUTION OF NAVAL ARCHITECTS,

FIRST LORD OF THE ADMIRALTY,

TO WHOM

GREAT BRITAIN IS INDEBTED

FOR AN

IRON-CLAD FLEET,

THIS WORK IS INSCRIBED,

BY

HIS MOST OBEDIENT SERVANT,

THE AUTHOR.

# PREFACE.

The continued want of success which has hitherto attended all the attempts, which have been brought to a practical test, for preventing the fouling and corrosion of iron ships, and the many cases of fouling and corrosion which have come under the Author's notice, induced him to turn his attention to the question, with the view, if possible, of detecting the cause of failure.

In the course of his researches he collected a great amount of facts and particulars, and the serious and increasing magnitude of the evil became so striking that he resolved to embody them with some remarks and statements on ships of wood and iron, with the view of directing public attention to so momentous a subject, and pointing out a ready and practical means by which these evils can be removed.

At the present moment the prevention of fouling and corrosion in iron ships and vessels is still held to be unaccomplished, and the magnitude of the evil, as a whole, is comparatively unattended to, its existence being only occasionally recorded in the naval intelligence of the daily papers, or brought under the notice of the members of scientific institutions.

It being generally considered needful that, when statements are made or opinions advanced, proofs in support of them should be adduced, sufficient well authenticated examples are given out of an immense number which have been collected; and the opinions of most of those who have experimented upon or gone into the questions involved in the two points of corrosion and fouling are brought forward to corroborate the statements and opinions of the Author.

The plan by which the fouling and corrosion of iron ships are prevented, and which has been brought forward by Mr. T. B. Daft, C.E., is in all respects the soundest, simplest, and most practical, and, from being arranged in accordance with the known laws of nature, most certain of success. On these grounds the Author gives it his best support, and has endeavoured to prove that it is in all respects capable of fulfilling the requirements sought to be obtained. It is believed that this will be amply shown to all who have given any attention to the subject.

C. F. T. Y.

7, Duke Street, Adelphi,
London; *March*, 1867.

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## CORRIGENDUM.

Page 81, line 11 from bottom, *for* " iron " *read* " some."

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*Directions to the Binder.*

Frontispiece, to face Title-page.
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*The Illustrations are by the* London Drawing Association.

# THE FOULING AND CORROSION

# OF

# IRON SHIPS.

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## CHAPTER I.

### WOOD.

Wood, so far as history shows us, seems to have been the earliest material employed in the construction of boats or floating bodies, to carry or support anything on the water; and this, from its less specific gravity than water, and its almost universal distribution on the face of the globe, together with the comparative ease and readiness with which it could be worked and put together, render it well suited for the purpose; consequently, its employment for ships or boats may be called universal. Popular prejudice, from its long use, is strongly enlisted in its favour, and this has contributed most powerfully to keep it in use during the past five-and-twenty years, in many cases where its employment is a disadvantage rather than otherwise.

Whatever advantages it may possess as a material for the construction of boats or ships, from its less specific gravity, the ease with which it can be worked and put together, and its general distribution over the surface of the globe, are in the present day of large ships and powerful engines more than counterbalanced by the following disadvantages, which it is well known and generally admitted to possess, and these may be classed as follows:—

First, the supply is decreasing; next, great difficulty exists in obtaining it of the dimensions now required; next, its great bulk in proportion to its strength; next, the great difficulty if not impossibility of building very large ships of proper strength; next, its great size in proportion to its weight; next, its want of uniform strength; next, its want of durability; next, its liability to dry rot, the ravages of the worm, and damage from the sun and water;

next, its inflammability; next, it increases in weight as the ship gets older; next, the great difficulty of fastening it securely together; and lastly, its want of durability under any circumstances.

Where expedition in constructing wooden ships is required, there durability has to be sacrificed, and of this examples without end are not wanting.

To obtain durability in wooden structures it is most important that the wood should be thoroughly seasoned, and this can only be obtained by keeping it under those conditions most favorable for this purpose, and giving it sufficient time to become freed from the sap and juices contained in it.

It also should be felled at that season of the year when the sap is down, and the tree as it were torpid, for if it be cut in the spring, when the sap and juices have begun to move or circulate, the value and durability are both most seriously compromised if not destroyed. In tropical countries it has been found that timber felled when the moon is on the increase becomes shaky, and its durability seems to have left it; and there can be no doubt that a similar influence, though possibly in a less degree, exists in countries north and south of the tropics on timber felled at that period.

The delays that have occurred in the construction of the large wooden ships of war which have been built of late years, from the difficulty of obtaining timber of the required scantling, and particularly of the necessary forms, are well known; and the increasing difficulty of meeting with a sufficient supply of home-grown timber has been a frequent cause of complaint. Of late years oak and other foreign timbers, have been largely employed in the construction of wooden vessels, but it seems that the advantages gained by their employment are considered very questionable, and they are generally admitted to be very inferior to home-grown timber as formerly obtainable.

During the late Russian war, from having no stock of ships to use, great exertions were made to have such ships as were required built; but the great scarcity of seasoned timber necessitated the employment of inferior material; and what with inefficient inspection, unsettled action, hurried work, and alterations during construction, there resulted a costly expenditure with most unsatisfactory returns on the outlay; a little of which may be learned by perusing the Report on the Gunboats published in 1860, as the result of an inquiry by a Parliamentary Committee.

Mr. Corry, when Secretary to the Admiralty in 1846, admitted that "by far the largest portion of the timber used in the construction of ships is of foreign growth; and it is therefore a material point if iron, which is easily procured in this country, can be safely applied to the building of ships of war; and secondly, if there were a sudden demand for an increase of our naval force, as there was when the well-known 'Forty Thieves' were built at once, it would be totally impossible, either in our public dockyards or in the ship-yards of private builders, to find a sufficient quantity of seasoned timber, and the necessary consequence would be a premature decay of those built of timber unfit for use."

The readers of this will remember how exactly all this came to pass during the late war with Russia.

Wooden ships gradually absorb the water in which they float, becoming sodden or watersoaked, as it is termed, which adds perceptibly to their weight, decreases the speed of the ship and the durability of the material, and sets up chemical action in the metals used in her construction, whereby their holding powers are diminished and the tendency of working amongst the pieces forming the hull greatly increased, both of which are slow though certain causes of destruction.

In 'Engineering' of August 9, 1866, it is stated that "a 600 ton wooden ship, after being three years afloat, will absorb by soakage from forty to sixty tons of water, increasing the draught from six inches to nine inches, thereby increasing the positive resistance and reducing the speed."

That a wood navy is not economical to maintain, in proportion to the amount of service or duty obtained from it, is very generally known and as generally admitted; but whatever disadvantages belonged to it as a sailing navy, these have been enormously increased since steam propulsion and armour-plating have been introduced; in fact, it may be said that the conditions required to ensure the advantages of these two systems cannot be economically or satisfactorily obtained by the employment of wooden hulls.

Mr. C. Seely, the member for Lincoln, who has endeavoured to analyse the cost of our ships, stated in a speech at Lincoln, on the 23rd January, 1867, that "the 'Frederick William' had cost £281,691 in *repairing*, when a similar vessel could have been *built* for £134,453!"

He also stated that he found "five vessels had cost £230,090 for repairs, which vessels could have been built for £152,148!" He further stated—"The Admiralty have never disputed my figures with regard to the cost of ships, or if they have, they have afterwards had to admit that I was correct."

He also found that in one yard alone the loss in converting the timber used for shipbuilding amounted to £35,126, which was more according to the Government authorities than it ought to have done.

It was stated in the results of a Parliamentary Committee in 1848, that at fifteen years of age wooden ships of war require "very considerable repairs," and that the average age at which wooden ships are "broken up" is thirty-seven years; but it does not tell us how often such vessels have been "rebuilt" in that period. One thing, however, seems to have been overlooked in this report, and that is, the average amount of *work* done by each from the time of her *launching* to the time of being *broken up*, from which some data might have been arrived at as to the economy of wood ships for a given amount of *duty* at a given *cost*; and to this might then be added the *additional cost* at which these ships had been *maintained* in a condition fit for service.

It would be an interesting and valuable record, if a correct return could be got of the cost of building and maintaining the hulls of each wooden ship in Her Majesty's navy since, say 1845, with the number of years' service each ship had given in return for the outlay, so as to enable an average to be obtained of the cost of wooden ships. A similar plan exists on railways with regard to locomotives, by means of which the cost, maintenance, mileage, and duty done by each are easily obtainable.

There can be no doubt that the results of such an investigation would prove most astonishing and instructive, and afford some insight into the causes of the vast expenditure which has been incurred for a wooden fleet during the past five and twenty years; though it would, it is to be feared, fail to show a single justification for the continued and exclusive employment of wood in place of iron as a material for construction, which has so long been suffered to exist, and which desire even at the present moment seems as vigorous as ever.

The following statement of the cost of maintenance of some wooden ships of war, which had all more or less been affected by dry rot, will give some idea of the great expense entailed by the employment of wood as a material for the construction of ships:

"Ardent" when new cost £23,000; she was launched, but *never went to sea*; at a later period she was found to require repairs which involved the expenditure of no less than £17,000; soon after this *the decay was so rapid that she had to be broken up!*

"Superb."—This ship cost £38,000 to build; after she had been in service two years and a half she was found to require repairs which cost no less than £47,000! whilst the total amount of service got from her only amounted to *eleven years!*

"Achilles."—This ship cost £36,000 to build, was one year and eight months in commission, when she was repaired at a cost of £25,000, and in seven months more was paid off.

"Ajax."—This ship cost £39,000 to build; after five months' service she was repaired at a cost of £26,000, her entire service being *four years*.

"Spencer."—This ship cost £36,000 to build, her repairs amounted to £43,000, and her service to *two years*, when she was paid off.

Taking, then, the services of the vessels in return for the outlay, we find that in the case of the "Ardent" *no return was had in the shape of service;* consequently, £40,000 *were entirely thrown away!*

The "Superb" gave eleven years' service on an outlay of £80,000, representing £7272 14*s.* 6½*d.* per annum.

The "Achilles" gave two and a quarter years' service on an outlay of £61,000, representing £27,111 2*s.* 2½*d.* per annum.

The "Ajax" gave four years' service on an outlay of £65,000, representing £16,250 per annum.

The "Spencer" gave two years' service on an outlay of £79,000, representing £39,500 per annum!

In 1812 the "Devonshire," 74, had her bottom planks cut from the *best* kind of American white oak that could be procured; but although the ship had never been sent to sea, when examined in 1817, a period of five years, these planks were found to be *totally decayed.*

The "Halifax," sloop-of-war, was built at Halifax, and launched in October, 1806. The birch, red pine, and oak used in her construction, were all grown in that neighbourhood; *but the vessel was found unfit for service* in January, 1812, at the end of the short period of six years!

The impossibility of combining the pieces forming the hull of one of the large class screw frigates which have been built of late years in such a way as to ensure strength and durability, when wood is the material used, is admitted by many, and that none of them, however carefully and scientifically constructed, could stand for twenty-four hours the strain exerted by the engines when at full power. Even the few hours occupied in a trial trip are found to strain the after portions of the hull, causing the oakum used in caulking the seams to start, and leakage to follow as a matter of course, and this in spite of knees, riders, and straps, both of iron and wood.

If, as is stated by Mr. Chatfield, of Her Majesty's Dockyard at Devonport, the average durability of our sailing wooden men-of-war, when employed in active service, is about thirteen years, when built of oak, it would be an interesting piece of information to know how long these same vessels would last if propelled by the screw, and what the cost of their maintenance in proper and safe sea-going order would amount to, if called on to perform in regular work a similar amount of duty to that which can be obtained from a well-constructed iron vessel of similar power and proportions.

So well known and admitted are the disadvantages of wood, when used as the sole material for the construction of ships, that many builders have taken up the plan of constructing what are termed "composite" ships, or vessels with the frame or ribs made of angle or T-iron, covered with wooden planks; and the success which at the commencement has resulted from this mode of construction seems to have led to its increase, and to vigorous exertions being made to cause its more extended adoption.

Now, in this case, the superiority of the results obtained over what can be got by the use of wood alone, seems fully to prove that the *entire use of iron* would give far more satisfactory results; and that this must inevitably be the case is equally certain, were it not that a serious evil, or rather two evils, are introduced, namely, fouling and corrosion; and that up to a very recent period no means of preventing them, in a simple, easy, and effectual manner, had been found, must be attributed the introduction of the mixed or "composite" system of construction.

Dr. Fairbairn has well remarked that "wood-sheathing, when attached to iron ribs, is, to say the least of it, *a weak and unsatisfactory construction.* Composite structures of this kind, where *strength* is required, *are never safe,* for the two materials are so *widely different in character* as to produce, by their union, a source of weakness of a most unsatisfactory description; and they are therefore not to be compared with vessels framed exclusively of iron, nor even with those entirely composed of wood.

"From the great difference which exists between the resisting powers of iron and wood, it is evident that *any* combination, *however well executed,* is not calculated to insure the requisite strength for sea-going vessels subject to severe strains. On the contrary, it appears obvious that a vessel constructed with iron frames, and covered with wood-sheathing, is a decidedly weak and unsatisfactory structure. It is true that a vessel of this kind may be strengthened by stringer plates and diagonal bracing; but to do this is not to adopt the form the best calculated to give the required strength: it would be preferable and cheaper to make the ship entirely of iron, and dispense with the wood-sheathing altogether." He concludes by saying "that the system is *not* an eligible one, and, for sea-going ships, is *utterly at variance* with *sound* principles of construction;" and he further says, "for large ships intended to navigate the open sea, this construction cannot be recommended, either on the score of *economy* or *safety.*"

The 'Times' of the 10th January, 1867, announced in the "Naval and Military Intelligence," that seven new vessels are to be built, four of which are to be "timber built, with *iron* deck-beams and stringer plates;" the three gunboats have these "great features in the design and fitting, that they will be built with *iron* frames, covered with an outer skin of two thicknesses of teak."

A few moments' reflection ought to show to any thinking, practical man, that if the weak material, wood, is strengthened by the addition or employment of the stronger material, iron, as a component part of the structure, that the *entire* use of iron in place of the confessedly weak material, wood, would not fail to be a more certain and satisfactory mode of procedure, and the one most calculated to give good results as regards safety, economy, and efficiency.

In 'Engineering' for April, 1867, it is remarked that "the objection to composite ships is that they are not as cheap or as strong, with the same weight, or as tight, as iron ships; but a still greater objection lies in the difficulty of fixing the planks to the iron frames by any expedient which will not involve corrosion by galvanic action. If the wood is bolted to the iron by iron bolts, the coppering, when applied, will quickly waste these iron bolts, so that they will become unsafe; whereas, if the attachment is made by means of copper bolts, the bilge-water within the ship will cause the copper nuts quickly to corrode the iron frame."

Mr. Scott Russell has well observed that "half of the entire timber in a ship is merely occupied in strengthening the butts and closing the joints of the other half; whereas the waste in an iron ship will not be one tenth." Further on he says: "A large ship built of wood is much weaker than a small ship built of wood. The reason of this is that wood, being grown, the pieces of which it is composed cannot be got proportionately larger as the ship is larger. Thus, the planks of a small ship may be a foot wide and thirty feet long; but planks for a ship three times the dimensions could not be found three feet wide and ninety feet long; and this holds all through the ship: the bits of which it consists are a multitude of small pieces, more multitudinous and smaller in proportion as the ship is larger."

Admiral E. P. Halsted, in his 'Lectures on Iron-cased Ships,' naming some of 600 to 1000-horse power, says, "I doubt if it can be shown that any single frigate of the steam power I have named has ever yet tested the ability of her frame to bear the stress of her machinery at *full work* for any forty-eight consecutive hours, perhaps not even for any twenty-four."

It has been remarked by a writer in 'Temple Bar' for 1860, and who is generally believed to have been educated as a wooden builder, that "the strain upon the wooden sternposts in some of our fastest and finest ships, like the "Orlando" frigate, for example, is so enormous, especially whenever the speed is forced at all, that the whole fabric of the ship trembles and shakes to such a degree that the vessel would soon be rendered unfit for service; even the topmost spars feel the shake in these vessels of very great steam power. Therefore in modern naval warfare, as great steam power—*grande vîtesse,* as our neighbours have it—will be indispensable, we must have iron sternposts, and no doubt also iron ships. Nothing else will stand the tremendous strain of the screw;

and if ships of war are to be made shot-proof, the whole skeleton of the ship must be of iron, as well as the muscles and skin. The Emperor Napoleon, it will be found, has a little overreached himself, and perhaps hurried his able architect, M. de Lôme, in converting his ten good wooden ships into cuirassed frigates *à grande vîtesse.* Shot-proof they may be, but they can never stand the shake of the screw and remain weather-proof for anything like the time that iron ships can."

Admiral E. P. Halsted stated at the Institution of Naval Architects, in 1864, that "the wooden flagship of the present admiral commanding the Channel squadron, when lashed to the basin-walls at Sheerness to take a first 'grind' out of her engines, was seen with the oakum streaming from every seam in her quarters; both her rudder-posts rocking to every stroke of the engines; the whole ship trembling in the hands, as it were, of that rushing cylinder of water; while the master shipwright shouted with uplifted hands, 'For God's sake, stop those engines, or you'll drive the stern-posts out of the ship!'"

Mr. Scott Russell said, in 1864, at the Institution of Naval Architects, "that bits of wood kept together with bits of metal cannot stand the continuous day-after-day wear and tear of the wriggle of a 1000-horse power screw in the tail of a ship. It is not in the nature of the metal fastening of a wooden ship to sustain that continuous wear and tear."

Mr. Grantham has remarked (Institution of Naval Architects, 1865), "We have never found that the power of the screw could be applied in a wooden ship without great, expensive, and massive fastenings; and as long as you have a ship planked, as wooden or composite ships must be, they will be shaken by the excessive action of the screw. We know that Government, with all their appliances, have never yet been able to overcome this difficulty, and that when they have tried to work our wooden ships to their full power, they have frequently been obliged to stop the engines, owing to the excessive shaking in the afterpart of the vessel; and the result has been most serious. I come back, therefore, to the conclusion that an iron ship is essential, and that the reason why they are not universally adopted is their fouling."

Mr. W. B. Robinson said, "I know that some of our ships in the navy have been obliged to stop full steaming in consequence of their sterns being too weak to bear the action of the screw."

The construction of wooden ships to be sheathed with thick and heavy iron armour-plates is a great error, and it can only be justified by necessity, or where time would not admit of the construction of an iron ship. The argument that *because* there is a great quantity of wood in store, and that it would be better to use it for building ships to be cased with iron than to *sell it,* or that *because* wooden ships are *partially* or *entirely* built, it is *cheaper* to case them, *cannot be justified for one moment on the score of economy,* as it is a certain fact, that the maintenance of such vessels is very costly, and their durability—a most important point—is very problematical.

It is very true that a *wooden* sea-going iron-clad is better than *no* ship at all, if we take it on the question of being possessed of a ship of *any* description; but the most important part of the subject—that of having *useful, serviceable, safe, economical,* and *efficient* vessels—seems to be quite overlooked in such arguments. It is a serious question, whether it is not better to be without sea-going vessels at all than to go to the great cost of building bad or useless ones, fitting them out with expensive engines and armaments, filling them with men, and sending them out to encounter, possibly, a smaller one, but properly built, and perhaps in a few moments being either knocked to pieces or sent to the bottom, without having inflicted a proportionate amount of damage on her opponent. In this case, it would be cheaper and better, either to have had a proper ship or else to have had none at all. There can be no doubt that the old saying, "The *best* is the *cheapest,*" applies with great force to this state of things.

The state of the "Prince Consort" after her cruise in the November gale in 1863, will sufficiently show the disadvantages of a *wooden* hull loaded with heavy iron plates, and its inability to withstand such a storm as an iron hull equally loaded would do with impunity.

The same argument will also apply to the case of building large and untried experimental iron ships, into which are put expensive engines, and armaments, together with skilled and trained crews, which, without due tests, are sent away to teach us their deficiencies, at more than probably the loss of the entire ships and men, from some unknown or unprovided for contingency. Let us have experimental construction, armaments, and engines, by all means; but do not let obstinate adherence to or undiscriminating prejudice for antiquated practice, prevent such fair unbiassed and thorough examination and tests, as will plainly show and certainly settle the advantages or disadvantages belonging to each.

Mr. E. J. Reed, the chief constructor of the British Navy, in his lecture on "Armour-plated Ships," which he gave at the Plymouth Mechanics' Institute, on the 7th December, 1866, when speaking of the existing wooden fleet, and converting them into iron-clads, says—"These ships are all more or less decaying even now, and by the time their conversion was completed they would be in a worse condition of course. Again, they are not, as a rule, fast ships even at present, certainly not equal to our first-class iron-clads by a great deal. The proposal involves, however, the sinking of them much deeper in the water, and thus reducing even the speed which they now possess. I have also made a rough estimate of the cost of converting these ships upon this plan, and believe it would amount to £140,000 per ship. And let us presume that £120,000 would cover the cost (and this is less than the cost of the "Royal Sovereign's" conversion, although she has armour that is not now shell-proof, and has not been fitted with sea-going appliances), and let us presume that twenty-five such ships are converted. Then we shall have to expend three millions of money upon the transformation of these old line-of-battle ships into comparatively slow and inferior iron-clads, the whole of which together would be unfit, I fear, to cope with one such ship as might be built for one sixth of the cost, viz., a ship plated with fifteen to sixteen inches of armour, carrying twenty-two guns, and steaming at a speed of fifteen knots. It may be added that all these line-of-battle ships have weak and exposed sternposts and rudders, and are incapable of being used securely as rams."

The Secretary of the American Navy in his last report, speaking of wooden ships plated with heavy iron armour plates, says—"Armoured vessels for ocean cruising must necessarily be of large size, which cannot, with the requisite strength, be secured in wooden structures. If attempted, the immense masses of timber must rapidly decay, and the cost resulting from deterioration will be such as no economical and prudent nation will consent to sustain."

The 'Scientific American,' speaking of wooden armour-plated ships, remarks—"It is undoubtedly the part of wisdom, in the case of the English navy, to begin *de novo*. It is folly to suppose that those wooden hulls, when razeed and loaded with iron of sufficient protective thickness at and near the water line, and carrying immense turrets, could withstand the assaults of thoroughly built monitors. *They were not constructed for such kind of warfare as must be waged on the seas hereafter*. Of how much service would they be in such an encounter as that between the Austrian and Italian fleets at Lissa? Even the Re d'Italia, immensely stronger than any wooden ship could possibly be, could not stand the shock of ramming, although almost impenetrable to shot. There is a vast difference between wooden ships built for plating, and those built for the old style of naval warfare. These last are not fit even for harbour defence or floating batteries. Under the fire and direct assault of true iron-clads, they would become the coffins of those who put their trust in them."

The inefficiency of wood, and its weakness when used for the construction of modern ships of war to be used as rams, was well exemplified in the case of the "Amazon," which, whilst in the Channel, ran foul of another ship, and with the other sank in a few minutes, from the effects of the shock; the bows being wrenched and the whole hull shaken.

It is believed that this vessel, for her size, was as strong as it is possible to make a wooden ship, and as she was built and fitted out with all the appliances which extended experience and the highest scientific knowledge and skill could afford, it would seem that this is correct.

Captain Cowper P. Coles, speaking at the Institution of Naval Architects, in 1866, of the benefits to be derived from preventing the fouling of iron ships, says—" It will also relieve us of the great difficulty of building small *iron* cruisers to carry heavy guns for the protection of our commerce in all parts of the globe, and eventually admit of our relinquishing the expensive and wasteful system of building these vessels of the inferior material *wood* for the sake of coppering them. I say wasteful advisedly, not because of the first outlay in these wooden men-of-war, but because of their speedy decay and constant need of repair, inherent to their weakness in carrying heavy guns, or engines of high power, and I hope eventually to see iron cruisers of great speed, mounting one or two of the heaviest guns, either wholly unprotected, or with a mere belt, and the guns mounted on the central armament principle turret-wise. With our vast possessions and trade we require numerous fast cruisers, and we must always feel the enormous cost of our navy; but in peace let us harbour and economise our resources not by cheeseparing and shamming retrenchment, or cutting down our navy, but by considering measures well before we adopt them, and in building all men-of-war of material that may last for many years, instead of wood, when we shall not see vessels annually sold out of Her Majesty's navy "for a mere song" to be broken up for firewood, which even in their short lifetime have cost more than their original value in repairs."

It is now perfectly evident that the requirements of the times imperatively demand the employment of a better material than wood, and although wood has held its place from it may be said "time immemorial," it now appears that its use must be discontinued and iron take its place.

Mr. A. M'Laine, in his paper read before the Institution of Naval Architects in 1865, has remarked that "wooden ships of war may perhaps with propriety be passed over without consideration, as a complete anachronism in the present advanced position of naval construction." And to this it may be added, that the "composite" system of construction, in spite of its being so strongly advocated as it is by many persons, should be placed in the same category, as having *less* claim on our attention than ships constructed entirely of wood.

# CHAPTER II.

## IRON.

Iron, as a material for the construction of ships, boats, &c., is, comparatively speaking, a modern device, its use for this purpose not being authenticated prior to the last twenty years of the past century; and although the results attained by its use were most satisfactory, still prejudice, when added to some serious defects which have hitherto been inseparable from its employment, has successfully retarded its merits being appreciated, until a comparatively very recent period.

The great and hitherto unconquerable defects of iron, when used for the construction of sea-going vessels, have been—its rapid fouling from barnacles, zoophytes, weed, &c., and the still more fatal and dangerous one of corrosion, or the rapid and certain destruction of the material of the vessel itself by the action of the sea-water in which it floats. To these may further be added the serious losses which have occurred from the employment of inferior metal, an improper and ill-judged mode of putting it together, and badly designed forms and plans for the vessels constructed from it. All these, and the popular prejudice that "iron won't swim," and if it could, that it "wouldn't be safe," have contributed enormously to retard the spread of iron as a material for the construction of ships.

Against these defects and objections must be set the following advantages, which are well known and admitted to exist:

First.—It is abundant, it is cheap, it is inexhaustible, it can be easily manufactured, it has great strength, it has small bulk, does not increase in weight by absorption, it is very durable, can be combined so as to give the maximum of strength, can be securely fastened, does not limit the size of ship that can be built, not limited to form; in short, it may be said that there are no knots, no sap, no cutting across grain, no different strengths according to position, no yielding, as in a wood ship.

It has been said that "iron has a thousand claims to our suffrages, whilst wood has very few; and that in future ages, when wooden vessels will have ceased to hold any existence but in the pages of the historian, mankind will begin to wonder at their own temerity in having trusted their lives to such fragile and precarious structures, as wooden ships will then appear to them to be."

The strength and advantages of iron as a material for construction are well known and unquestioned. Dr. Fairbairn remarks that "wrought iron, as a material for the construction of ships, possesses advantages over every other kind of material. Besides other advantages, it possesses great strength, durability, and lightness; it may be hammered into any requisite shape, and one piece may be securely united to another by welding or by riveting, so that comparatively small pieces may be so united and combined as to form the strongest and most ponderous ship."

One iron top will wear out three bottoms, as was proved in the case of the "Jamaica," of 421 tons, built at Glasgow; the "G. F. D.," built at Newcastle in 1849, and numerous other cases.

In the introduction to Lloyd's Rules it is said that, "although iron is about eight times heavier than oak, at the same time being ten times stronger than oak, from the facility of uniting the parts together by welding or riveting, a ship can be constructed of greater general strength of iron than of oak, while it may be lighter, thus having more displacement for carrying cargoes, and if the surfaces be *carefully preserved from corrosion,* it can be kept up in good condition at *less expense than wooden vessels.*"

Iron, it is true, is not exposed to injury from the worm as wood is, but it has its "dry rot," as it may be termed, in the shape of rust and corrosion, which are further increased by the presence of metals of a superior rank in galvanic power, when in a position to cause this dangerous and fatal action to be set up. No hitherto applied means have been successful in preventing this action, and as the certainty of this action and its fatal effects become better understood, there can be no doubt that such ill-judged attempts will be abandoned, and wonder expressed that they should have been for one moment thought of, proposed, or tolerated.

Mr. Holmes, in his 'Report on Steam Communication with India,' says, "Iron ships are especially calculated for the vast revolution in the navigation of the world which is at hand by steam-vessels superseding every other navigation or mode of sailing. Without iron ships this could never be, from the difficulty of building very large ships of wood to draw little water, with a due regard to those principles of naval architecture which are indispensable in their structure; and as far as relates to the strength, flotation, and control of them, there is no limit. So great, indeed, are the advantages of iron ships over those built of wood, that they only require to be known and understood to be universally adopted, to the exclusion of all others."

The principal advantages possessed by iron ships over those of timber are, greater strength than it is possible to attain by any known combination of timber, less weight, greater available internal capacity, with the same external dimensions, greater speed from diminished immersion, less cost of maintenance, and consequently less time lost for necessary repairs.

Iron admits of every part being more securely and intimately connected with each other than can possibly be done with wood, added to which is the important advantage that either "with the grain" or "across the grain," makes little or no difference in its strength or applicability.

Dr. Fairbairn, in his 'Iron Shipbuilding,' remarks that "a carefully riveted iron ship may be looked upon as *jointless;* and hence its value as a strong and durable structure. In short, an iron ship, with its iron sheathing (plating) riveted to the frames, may be considered as uniform in its powers of resistance, and superior to anything yet accomplished by any other material with which we are acquainted."

The rapidity with which iron can be worked up is one striking point of superiority of iron over wood. Instead of requiring many months, or perhaps years, to season in the timber-yard, having previously taken may be centuries to grow, the ore may be converted ready for shipbuilding in a few days, and in the course of a few months more may be ploughing the waves, propelled by the power of steam or that of a pleasant breeze.

Mr. Joseph H. Ritchie, one of the two principal surveyors of Lloyd's, in speaking of iron as a material for the construction of ships, says: "Although iron is about eight times heavier than water, and ten times heavier than oak, at the same time, being ten times stronger than oak from the facility of uniting the parts together by welding or riveting, a ship can be constructed of greater general strength of iron than of oak, while it may be lighter; thus leaving more displacement for carrying cargoes; and if the surfaces be carefully preserved from corrosion, it can be kept up in good condition at less expense than wooden vessels; hence the rapid increase in their numbers, which in thirty years has placed iron on a level with the material that had been used for shipbuilding in all countries for four thousand years."

Dr. Fairbairn well remarks, in his 'Iron Shipbuilding,' when speaking of the results obtained by the use of iron in the earlier vessels, "The strength and sailing qualities of the whole of these vessels were confirmatory of the great superiority of iron over wood as a material for shipbuilding; and we have only to refer to the extensive use and enormous increase that have taken place in its application, not only in this country, but in every maritime state of the globe, to be convinced of the soundness of the principle, and the great superiority of the iron ship."

When iron ships first came into use, every one almost prophesied their failure, chiefly because it was *metal,* and not *wood,* that was employed in their construction; and there can be no doubt that this prophecy was not a little strengthened, and its correctness proved, by the incomplete mode in which many of such vessels were constructed, and the want of due consideration of the strains to which they were exposed, the result being the breaking in half and foundering, if at sea, or the rapid breaking up of such as went on shore or were exposed to the violence of such gales as they might have encountered.

Mr. W. B. Adams, the well-known engineer, describes some of the earlier attempts at iron ships as "large flat-bottomed wall-sided open troughs of sheet-iron, rivetted together at the seams, precisely like a long tank fitted with a wooden lid in the shape of a deck. Form or proportion there was none, and the only framing was the deck beams."

Unfortunately, even at the present time, experience does not always show that such progress has been made in obviating known evils as ought to have been and still requires to be made; and in spite of the security professed to be obtained by "special surveys," exact conformity with "regulations" and "rules," "classification," &c., there have been constant proofs of their small utility, and more of their glaring inefficiency, many notorious and well-known examples being easily obtained if needed.

That sea-going ships of iron can be made as safe, handy, and useful as any wooden structure, and far more durable, cannot for a moment be doubted, and that wooden vessels can be, and are built of quite as dangerous a character as the worst iron one, is also equally true, but will not as a rule be so readily admitted. To say then from these facts that one material is better than the other because there have been some failures, but from their causes being known admitting of an easy remedy, is simply absurd, and the whole question turns upon which is the material most fitted for the requirements of the times, and the conditions they have to fulfil. The condition of the bows of the iron steam vessel which was exhibited by the Motala Iron Works, in 1862, at the International Exhibition, and which at full speed had run right against a perpendicular rock, will no doubt be remembered by many of the readers of this, and is a good proof of the great strength of iron ships when the proper quality of material is used.

The Controller of the Navy, in his celebrated statement relating to the "Advantages of Iron and Wood in construction of Ships," published in 1863, remarks—"*Great addition* to the strength of the wooden structures is given by *iron* beams, *iron* decks, filling in between the timbers, diagonal bracing, &c.; and taking all the circumstances into consideration, it seems decidedly preferable *at the present time* to build these ships in our dock-yards of wood, rather than in private yards and of iron."

Now one would have thought that seeing the "great addition" which is given to the strength of a wooden structure (in itself without it a very weak and unsatisfactory production) *by the use of iron*, it would have been self-evident that a ship constructed *wholly of iron*, the material which gives a "great addition to the strength," of a wooden hull, would have given far more satisfactory results than the patched-up weak wooden one; but this it seems the Controller does not admit, although extended and extending experience gives ample proof of the truth of it.

The Controller of the Navy, although preferring wood to iron, admitted that "an iron ship can be built of larger dimensions than a wooden ship, with no loss of strength."

That "an iron ship has more rigidity and strength of structure as a whole than a wooden ship, though locally weak and liable to be penetrated by blows which would fall harmlessly (?) on a wooden ship."

That "an iron ship has much greater durability in certain parts of the structure, indeed in all parts where the wood is in contact with the iron, than a wooden ship; and after a lapse of years the iron frame would have suffered next to nothing as compared with a wooden ship."

Against these admitted advantages he urges the following disadvantages, as reasons why ships wholly of iron should not be built, and if all of them could not be overcome, no doubt they would he of serious moment:—

First, there is "the serious local weakness of the comparatively thin plates of which the bottom of the ship is necessarily composed," which gives rise to "the danger consequently of getting on rocks in such ships."

Secondly, "The necessity which this weakness entails of constructing double bottoms, thwartship bulkheads, watertight compartments, sluice doors, &c., and various other complicated arrangements which add both to the weight and cost of an iron ship."

Thirdly, "The rapidity with which the bottom of an iron ship gets foul, and the immense loss of all the ship's qualities that follows from the adhesion of marine zoophytes. No practical remedy has been found for this serious disadvantage; repeated docking and cleaning is the only palliative."

Fourthly, "The extreme uncertainty as to the quality of the material used, in fact, the small quantity of real good iron of the best ship-building qualities that can be found in the market."

Fifthly, "The prodigious ravages caused by the splinters of iron when the plates are broken and smashed by shot."

Sixthly, "The far greater facility with which iron ships can be pierced below their armour plating by submarine guns than wooden ships."

It will be desirable to examine and reply to each of these, so as to find what amount of weight is to be attached to each.

In regard to the first part of his objections, there is some truth in it when ships are badly built; but experience has shown in the case of the "Nemesis," the "Cleveland," the "Lady Lansdowne," the "Royal George," the "Garryowen," the "Iron Duke," the "Great Britain," the "Vulcan," and hosts of others, that this casualty may happen with greater impunity and less risk of the loss of the ship than in the case of a wooden vessel, especially when properly put together and fitted with water-tight bulkheads.

As to the assumed weakness "entailing" all sorts of "complicated arrangements" which add to the weight of the ship, it is well known that a *wooden* ship is a *far more* complicated structure than an iron one, and *much weaker;* and, in fact, to strengthen such a ship *iron* is found necessary. It is well known that, comparing a wooden and an iron ship both of precisely similar external dimensions, the iron one will carry more and be lighter in the proportion of five to six than the wooden one; therefore this objection is of no moment—whilst in regard to the greater cost of an iron ship the result is a more durable and stronger vessel, and one far cheaper to maintain; and if the work got out of each during a given period be contrasted with the sums expended in maintaining them during that period, there can be no question that the results will be greatly in favour of the iron ship, assuming, of course, that both are equally well constructed of their respective materials.

So far as the objection of fouling and corrosion of the hulls of iron ships go, and which have up to a recent period been most serious objections, these are now entirely overcome by Mr. T. B. Daft's patent plan of constructing and sheathing iron ships and vessels, which will be found fully described towards the end of this work.

As to the objection respecting the "quality of the material used," and "the small quantity of real good iron" that "can be found in the market," this cannot be for one moment entertained. Such a remark well applies to the case of *wood,* a material the supply of which is constantly decreasing, is slow in growth, and anything but desirable; but this statement respecting iron cannot for one moment bear examination. Bad iron may be bought just as readily as bad wood—perhaps it may be said *not* so readily, but to say that our great ironmasters cannot produce any quantity of good iron, of any quality that may be required, argues a general deficiency in the knowledge of our iron trade and the resources of British industry.

Low-priced wood cannot be of the quality required for the construction of first-class ships, and, whether good or bad, wood will waste more in conversion than iron, with this serious disadvantage, that the waste cannot be worked up again as the iron can.

It is usually understood that the best article requires the best or highest price; and that where a demand exists, there the supply will be generally found. The same with our iron: if people *will but pay the price of the proper quality, any quantity* can be made; but to suppose that *good* iron can be supplied at the *same price* as the *inferior quality,* which from motives of "economy," *has been too much regarded of late years,* is a very great mistake.

The objection of the "ravages caused by the splinters of iron when the plates are broken and smashed by shot," would no doubt be of some moment were it the fact that the bare iron shell of some $\frac{5}{8}''$ or $\frac{3}{4}''$ in thickness were exposed without protection to the full force of the shot; but as all ships which are likely to be exposed to this contingency are built with armour plates of a thickness pronounced to be sufficient to prevent this effect, it is needless to make further remarks on it.

In regard to the greater facility of iron bottoms being penetrated by "submarine guns" than wooden ones, there are no such guns at present in use; but were there such, iron affords such enormous facilities of adaptation, that little fear need exist on this head.

One thing is most certain, which is, that no "opinions" can stand against facts—especially where facts are fully and truly stated: therefore, whilst facts are in existence, and all relating to them fully understood and brought forward, there can be no doubt that "opinions" not backed by experience will quickly be rightly estimated, and consigned to that position they so rightly deserve.

"Opinions" have been, and too often are, the great opponents and banes of progress: for instance, they said a steamship could not carry coal enough to cross the Atlantic; that people would never sit behind a locomotive at a speed of twenty miles an hour—in fact, that they would just as soon be tied to the tail of a sky-rocket; that railways would never get enough people to travel on them to keep them going. In fact, it would be a waste of space to notice more, as the real value of such "opinions" are well known and rightly estimated.

One very curious objection made by the Controller of the Navy to the use of iron ships for the Navy is this—that none of the ships built by contractors have been completed in the time or at the cost specified, and *therefore* the building of iron ships is objectionable!—whence he deduces that "this clearly indicates the great uncertainty attending this mode of construction."

It would seem, however, that the "great uncertainty" has been in what each ship was to be like; and this, it seems, could only be found out during construction. Hence the endless alterations, delays, expenses, difficulties, &c., of which the Controller so loudly complains.

Then, again, he argues that unless such ships are built in Government establishments, "strikes of workmen, strikes of colliers, disputes in trades, all interfere with the progress of the work, and always to the prejudice of the Government."

It will be difficult to explain how this will not affect the Government work in their yards, unless they can show that their iron, coals, &c., are obtained by their own men, or from some country or locality where such things as strikes, &c., are unknown.

The whole truth of the matter is summed up in the following paragraph in his statement, which runs as follows: "If *wood* be the material selected, the place of building will be our own dockyard, with all the plant, appliances, and *material* at hand;" and that, therefore, because there is a good stock of wood on hand, and the yards and men are already in existence, it evidently follows that wood *must be*, and is, the *only* proper material.

The strenuous opposition maintained against the use of iron for constructing ships, both by "official" and "unofficial" persons, was for a long time successful, and delayed until a recent period the progress of one of the most valuable and important improvements of the age. So far as relates to there being the slightest reason in the senseless opposition to the employment of iron for shipbuilding manifested, as it has well been said, by "heads of wood" and "wooden heads," not one practical or reasonable one has been brought forward, and the conclusion irresistibly forced on one is, that *self*-interest rather than *public* interest in this case, as it unfortunately happens in others also, predominated; and the result has been costly expenditure, uncertain action, the loss of an incalculable amount of valuable time, no settled plan of construction, and general inefficiency throughout.

Dr. Fairbairn observes—"Thirty years' experience in the appliance of iron to the building of our mercantile navy has shown the great superiority of that material for shipbuilding; and much greater progress in this direction would have been made in the Government dockyards but for two reasons, namely, the strong prejudices engendered against iron in the first instance, and the dangers arising from the effects of shot on iron ships in the second."

There can be no doubt but that this second objection was not a little strengthened by the mode in which the resistance of iron plates to shot was tried, namely, on an old worn-out hull composed of thin plating less than a quarter of an inch in thickness!

And if it had been desired to test iron in such a manner as to *cause its complete failure for the purpose*, a better or *more certain* mode of action could not have been devised.

A great bar to the successful adoption of many a good and simple improvement, and to the saving of vast sums of money, exists in the fact that it is too much the habit of persons placed in the position of advisers, or invested with the power of adopting or refusing an invention, to consider that it is their duty to invent or improve upon any plan which may be submitted to them, and not to accept it in its integrity, even if it be the plainest and most undeniable thing that was ever seen. Such an idea as this is a great mistake, and in too many instances has been the cause of a great waste of time and money, and the perpetuation of much that is most undesirable.

The duties of such persons, and for which they are in many cases paid, is to have sufficient intelligence, knowledge, and practical understanding of the matters placed before them, to be able to see whether any advantage can be derived therefrom, and if so, to advise and assist in their *proper* carrying out. One of their greatest benefits should be derived from their *not* being inventors, but having the capability of sifting the good from the bad, the useful from the useless; and history has shown, and still from time to time places before us, the evils which are introduced and perpetuated by the reverse, but, alas! with but little benefit to any one.

A right appreciation of the duties involved by such a position will hardly fail to induce such attention and care being given to their proper discharge as must prove of the greatest benefit and advantage to all concerned.

Sir Howard Douglas, when consulted by the late Sir Robert Peel as to the use and efficiency of some six iron steamships that were being constructed for the Government, stated that "vessels wholly constructed of iron were utterly unfit for all the purposes of war, whether armed or as transports for the conveyance of troops"!

As Mr. Scott Russell has well remarked in his 'Fleet of the Future,' "Against the use of iron for war-ships, and even for any ships at all, the most inveterate prejudices have long existed in the minds of sailors, shipbuilders, and all who have made naval affairs their occupation. It is only the slow growth of intelligence, and the gradual formation of practical experience of the great benefits to be obtained by the use of iron, that has been strong enough to overcome some of these prejudices; and slowly, painfully, one by one, they are now becoming eradicated."

It has been well observed, that "to be convinced of the impolicy of overlooking improvements merely because they do not accord with preconceived notions, it is but necessary to look back for a moment to the numerous instances in which the most important and even palpable improvements have been checked and slighted by ignorance and prejudice."

The adoption of the screw-propeller in the Royal Navy was long delayed, even after practical proof had been given of its advantages, because some wiseacre, who had been a trip at a speed of ten miles an hour in a screw boat, dogmatically asserted that it would not answer, "because a ship propelled by the stern could never steer"!!

When chain cables were introduced for ships, a great opposition was started and maintained against them by a set of persons who seemed to think that "antiquity" was a recommendation; and this outcry was so far successful, that no ship provided with chain cables only, could be insured! *Now, every ship must be provided with them,* and rules have been made to decide sizes and lengths for each class of ship!!

It is needless to waste time or space in recording any further instances of the loss and injury which have been caused by ignorance and prejudice, inasmuch as few men of experience, and still fewer who are given to reading, will be without dozens of cases to prove the truth of this statement. Let us hope that increasing intelligence will remove this tendency, and lead those who meet with a subject they were unacquainted with before to take the trouble to understand it before pronouncing an opinion.

Unfortunately, to this day hundreds of thousands of public money still continue to be wasted, either by being expended on matters that are well known to be useless, or else by neglect in not spending such sums as would be productive of the saving required when the means exist by which this saving could be made.

Dr. Fairbairn, in his work on "Iron Shipbuilding," writes as follows of the drawbacks of iron: "The most prominent is that of fouling, and the adhesion of shells and marine growths to the immersed surface of the ship. This is a serious drawback to the application of this useful material; but we have reason to believe that some antidote for this evil—causing the retardation of speed—will in the hands of our chemical friends receive that attention which the importance of the subject demands, and that the time is fast approaching when immersed iron may become the repulsive instead of the attractive surface of adhesion. The subject of fouling, and the adhesion of barnacles to the hulls of iron vessels, has been since their first introduction a source of trouble and of difficulty for which no effectual remedy has been applied."

Mr. Grantham, in 1842, remarked that to prevent fouling, "chemical means will doubtless ere long be successfully employed for this purpose."

Mr. Mallet has observed that he considers it quite possible to render iron as much proof against oxidation as gold or platinum.

Iron, it has been said, from its "superior affinity for oxygen," is liable to rapid decomposition; and it has ever been a desideratum to discover some cheap mode of protecting it, the ordinary methods of painting and tinning not being sufficiently lasting.

The rapidity with which iron, when exposed to sea-water, both fouls and corrodes, and the almost impossibility of preventing these two serious evils, is well known to have checked the construction of iron ships; and so serious were these objections found, that in the year 1847 the Admiralty was actually intending to sell all those ships which they had of this material; in fact, they did actually begin to do so. About that time, however, a "composition" was brought forward which seemed to promise a remedy for, or at least a diminution of them; and this, although only partially successful, seems to have caused a reconsideration of the matter; and the extended use of iron ships in the merchant navy seems to have led the Admiralty to try the use of iron on a far more extensive scale.

In regard to the general use of iron for men-of-war, Admiral E. P. Halsted observes, "There would still remain at present the very grave objections against iron bottoms, of their liability to foul, and the consequent frequency of resort to the operation of docking."

Our new iron war-ships are vessels that ought to be able to maintain their speed throughout the term of their commission, and not to require docking every six months to enable them to keep at sea at all.

The cost of maintaining iron ships will be found extremely trifling, and but for the drawback of fouling, which necessitates constant docking, cleaning, and painting, the chief points would be the rigging and woodwork, which should not, however, require more attention or renewal than those of a wooden ship.

The cost of construction of the huge iron-clads we are now building may be taken at £50 per ton, builder's measurement, and £60 per nominal horse-power; to which must be added the cost of guns, rigging, masts, &c., stores, duplicates, and spare gear, which will be found to amount to a considerable sum, and one too large to bear much trifling with.

The Controller of the Navy, in his 'Statements relating to the Advantages of Iron and Wood, and the Relative Cost of these Materials in the Construction of Ships for Her Majesty's Navy,' printed by order of the House of Commons on the 3rd March, 1863, gives the cost of the

| | | TONS. | N. H. P. | | GUNS. | | |
|---|---|---|---|---|---|---|---|
| Warrior | of | 6109, | 1250, | and | 40, | as | £254,728. |
| Black Prince | ,, | 6109, | 1250, | ,, | 40, | ,, | £249,751. |
| Defence | ,, | 3720, | 600, | ,, | 16, | ,, | £173,478. |
| Resistance | ,, | 3710, | 600, | ,, | 16, | ,, | £178,576. |

Iron, however, with all its known defects, is steadily displacing wood as a material for the construction of ships; and there can be no reason to doubt that in the course of a few years wood will be a comparatively forgotten material, and only used under most exceptional circumstances, or where prejudice refuses to employ its great rival.

Without iron, it would have been impossible to construct such a ship as the "Great Eastern" or the "Himalaya," to say nothing of the huge vessels, such as the "Northumberland," "Hercules," and other leviathans in course of construction or about to be built, or to have any chance of making them either seaworthy or durable in any other material.

It is all very well, and sufficiently important in its place, to determine the size, shape, and appointments of our new iron fleet; but it seems quite out of place to do anything of the sort until the very base and foundation of the structure be settled. If our costly and magnificent broadsides, cupolas, monitors, or whatever they may come to, be dependent upon *any* description of paints or compositions, and be really wanted in service, they must all suffer seriously by corrosion and fouling before the end of their commission, or come into dock every six months to have their bottoms cleaned and repaired. Besides this is the value of a vessel which begins to foul from the day she leaves her port, and gradually but surely gets worse till her fine and boasted speed is reduced to two thirds, and then half, its original rate. Imagine such a ship in this case, with a clean-bottomed enemy, big or little, tormenting her, and the utility of such a ship to the country and the result of such a contest cannot be for a moment doubted.

Every objection which could, by the most skilled advocates of every other plan or device, has been raised and answered; and there remains only one straightforward and honest course to pursue, which is to adopt the simplest and best plan, and that which alone cannot possibly do any harm if it did no good, but which, at a moderate computation, it is calculated will save the Royal Navy hundreds of thousands of pounds sterling per annum, whilst its advantages to the merchant service cannot be of less moment.

Captain C. P. Coles, at the Institution of Naval Architects, in 1866, asks, "Is it to be wondered that iron should have been resorted to so generally as a material for shipbuilding, and that the *wooden walls* of Old England should have been superseded by *iron* *walls?* Iron, the marrow of England, is the source of her strength. Iron is invaluable as a material for shipbuilding, being capable of imparting to the structure beauty, high finish, and strength, fulfilling thus all requirements to perfection."

In spite, however, of the great and rapid progress which has been made in shipbuilding and scientific construction during the past twenty years, and the wonderful improvements in and facilities for the manufacture of iron which have been brought about, it is certain that much more will be done, and remains to do; and living, as we do, in an eminently practical age, abounding with the greatest discoveries and inventions, it may well be asked, "who can say that the 'ship of the future' has yet been discovered, or that the extent to which steam and iron will be developed is even as yet approximately ascertained?"

# CHAPTER III.

## CHRONOLOGY OF IRON SHIPS.

The first record the author can find of a boat or floating-vessel made of metal in place of wood is that of one built in 1787, by Mr. John Wilkinson, of Broseley, in Shropshire, who employed iron for this purpose.

This boat or vessel was 70′ long, 6′ 8½″ wide, drew between 8″ and 9″ water, and carried 32 tons of goods; was built at Willey, in Shropshire, and used on the Severn. It is most probable that she was a canal barge; but whatever she may have been, there can be but little doubt that she was the first iron vessel.

Another small boat, probably of a similar character, was built by Wilkinson soon after, which he employed to carry peat on the canal from the moors where it was cut.

In the same year, a vessel with the bottom constructed *entirely of copper*, without any plank whatever, was built; and another of a similar description in 1789.

In the year 1794, Brigadier-General Sir Samuel Bentham, K.S.G., constructed a small boat of copper, which he exhibited on the Thames, and also at Queen Square Place, Westminster.

In 1809, Richard Trevithick, the well-known engineer, and Robert Dickinson, took a patent, No. 3231, for several inventions embodying the use of wrought-iron plates. First, they described a movable caisson, or floating dock, made of this material. The internal figure resembled that of a boat. It had a flange six feet wide, extending horizontally outwards from the upper edge, for the workmen to stand upon, and also to strengthen the caisson; and it was surrounded by an air-chamber, or by air-chambers, consisting of wrought-iron plates, riveted together so as to form a semi-cylindrical hollow protuberance, extending along the sides of the caisson horizontally. Water was to be admitted into it until it was wholly immersed; and then, when hauled under the bottom of the ship, the water was to be pumped out.

Second, they described *iron ships*—"ships of war, East-Indiamen, and other large decked vessels." The decks as well as the sides of such ships were to be of plates of wrought iron, "riveted, or joined by screws."

Third, they proposed to make "masts, bowsprits, yards, and booms of *wrought iron,* out of plates riveted or screwed together in hollow or tubular forms. These masts being hollow tubes, the upper masts may be made to slide into the lower mast."

In 1810, Sir Samuel Bentham proposed to the British Government the introduction of *iron* for shipbuilding, on account of the increasing scarcity of timber; but the Admiralty refused to listen to his proposal. A guardship was just then about to be built for Chatham, and he endeavoured to get it built of iron; and as it would thus be constantly under the observation of the dockyard officials, the influence of that metal on the compass, as well as other objections, could be ascertained; but the Admiralty would not give their consent, and from this period the introduction of iron for shipbuilding was abandoned to private enterprise, and has received but little development from Government.

In 1815, Mr. Thomas Jevons, of Liverpool, built a small iron pleasure-boat, which he launched on the Mersey; and this seems to have been the first iron boat used in salt water. This boat was built by Mr. Joshua Horton, of Tipton, near Birmingham, and fitted up in Liverpool by Messrs. Hunter and Humble.

In 1818, Sir John Robison had an iron vessel (which he had designed in 1816) built for the passenger-traffic on the Forth and Clyde Canal, by Mr. Thomas Wilson, at Faskine, on the Monkland Canal, some six miles from Glasgow. She was called the "Vulcan," and was 61′×11′×4′ 6″; was flush or carvel built; had bulkheads with diagonal stringers; the frames were made from flat bar-iron, worked into the required shape in a cast-iron grooved block, and were placed 2′ apart. The plates were 2′ broad, and put on vertically; they butted on each frame, and there were consequently two rows of rivets in each frame. The keel was formed of two plates, ¾″×12″, placed side by side in a vertical position, reaching to the top of the floors. There was a "doubling strake" round the gunwale, made of ½″ plate, 13″ wide. This plate was turned into angle-iron 9″×4″, which gave great strength to the hull longitudinally, and supported the wooden stringer which ran fore and aft on each side. She had an iron lower mast, which was used as a chimney for the cabin-stove in winter, and did duty as a ventilator for the cabin in the summer, and the sides of the cabins were of glass.

It is stated that this boat was in existence in 1865.

In 1820, the "Aaron Manby," iron steamboat, was commenced at the Horseley Iron Works, and completed in 1821. She was sent up to London in parts, and put together in the Surrey Canal Dock, where she took in a cargo of linseed and iron castings, and, under the command of the late Admiral Sir Charles (then Captain) Napier, M.P., with Mr. Charles Manby (so long Secretary of the

Institute of Civil Engineers) as chief engineer, went from London direct to the Port Royal at Paris without unloading any portion of her cargo.

In 1825, the late Mr. John Grantham, of Liverpool, had a small iron steamer, of 10 nominal horse-power, built by the Horseley Iron Company, which he placed on the Shannon. The vessel was commenced in 1824, was put together in Liverpool, and sent across to Lough Derg.

In 1827, Mr. David Napier built the "Anglia" steamer, which had an iron bottom, and wooden sides above water, to ply on Loch Eich. She was afterwards called the "James Gallacher," and plied on the Clyde. Her dimensions were as follows:—Length, 62′ 8″; breadth, 13′ 0″; depth, 4′ 6″; gross tonnage, $49\frac{35}{94}$ tons.

In the year 1829, the late Mr. William Gravatt, C.E., designed, and had constructed by the late firm of Fenton and Murray, of Leeds, an iron paddle steamboat, with a horizontal tubular locomotive boiler, the paddle-shaft being placed in front of the smoke-box, against which the plummer-blocks were bolted. The lines of this boat were taken from a fine gig built by Roberts, boat-builder, of Lambeth. This is believed to have been the first steamboat in which a tubular boiler was used.

In 1829–30, Mr. Neilson, of Glasgow, altered an old iron passage-boat of the Forth and Clyde Canal Company, the "Cyclops," built in 1825, into a stern-wheel boat on the American plan, with a single engine of 14 nominal horse-power, and a single paddle-wheel; and though but ill adapted to give the required results, the boat proved so satisfactory that a second was built for them by Mr. Neilson.

In October, 1829, the first iron vessel built on the Mersey was launched by the well-known firm of Messrs. William Laird and Sons (the late Mr. William Laird and the present Mr. John Laird, M.P.). This vessel was 60 ft. long by 13 ft. beam, and 60 tons measurement. In the year 1831, two others of a similar size were built by the same firm.

In the same year, the firm (then known as McGregor Laird and Co., consisting of Mr. William Laird, the late Mr. Fawcett, and the late Mr. McGregor Laird, the African traveller) built and launched the steamer "Elburka," of 70 ft. in length, 13 ft. beam, and 15 horse-power, which went out with the late Mr. McGregor Laird, in 1832, as one of the Niger Expedition. This was the first *iron* vessel that ever made an ocean voyage.

In the year 1833 they built the "Lady Lansdowne" steamer, which was 130 ft. long, 17 ft. wide = 148 tons, and had engines of 80 horse-power; and the "John Randolph," of 110 ft. long, 22 ft. wide = 249 tons, and had engines of 60 horse-power.

In the year 1834 they built the "Garryowen," of 130 ft. long, 21 ft. 6 in. wide=263 tons, with engines of 80 horse-power; the "Euphrates," of 105 ft. long, 19 ft. wide=179 tons, with engines of 50 horse-power; and the "Tigris," of 90 ft. long, 16 ft. wide =109 tons, with engines of 20 horse-power.

The "Lady Lansdowne" was built for Ireland, and was sent out to Lough Derg in pieces—put together, finished, and launched there.

The "John Randolph" was for the United States, and was sent out in pieces to Savannah—put together, completed, and launched there; and this is stated to be the first *iron* steamer ever used in America, and she was still in existence up to the period of the late war, in good working order.

The "Garryowen" was completed and launched at the works at Birkenhead, and steamed round to the Lower Shannon, where she continued at work until 1866, when she was sold to go to the coast of Africa, after being carefully examined, and found in very good order, although she had gone through thirty-two years' hard work.

The "Euphrates" and "Tigris" were shipped in pieces by vessel to Beyrout, and with engines and boilers transported with great difficulty across the desert by General Chesney and the men of the Euphrates Expedition, and put together and completed on the Euphrates by men sent out by the firm. With the facilities of the present day, this would be a comparatively easy undertaking, but at the period it was carried out was certainly an arduous and novel feat.

The "Tigris" was lost in a hurricane on the river; and the "Euphrates," after working for many years as a steamer, had her engines and boiler taken out, which were put into another vessel, and her hull was used as a lighter on the river Indus.

All these early vessels were regularly built and framed like a wooden vessel, were very strong, and would have been fit to sail to any part of the world; and the "Lady Lansdowne" and "Garryowen" were capable of putting to sea under any circumstances.

In 1836, they built the "Eliza Price," to ply between Liverpool and Birkenhead, which was 85′ 8″ × 17′ 9″ × 7′ 9″=88 tons, with engines of 54 horse-power.

In 1839-40, they constructed for the Admiralty the "Dover," used to carry the mails between Dover and Calais. She was 110′ 5″ × 21′ 0″ × 10′ 6″, and when last heard of, a year or two ago, was on the coast of Africa, and in good order.

In the year 1830, Dr. William Fairbairn, in conjunction with his partner Mr. Lillie, built at Manchester the iron paddle-boat "Lord Dundas," for use on the Forth and Clyde Canal. The hull was 68′ × 11′ 6″ × 4′ 6″, built of light angle and T iron, with plates $\frac{1}{10}$″ thick, and had engines of 10 nominal horse-power, working a paddle-wheel placed in the centre of the boat, in a wheel trough extending the whole length of the hull. The light draught of this boat was 16″, and she could accommodate 100 to 150 passengers. Dr. Fairbairn informs the author that he made the voyage from Liverpool to Glasgow in her; and she proved so successful that his firm built eight more of a larger size within the next two or three years for Scotch canals; two passenger-boats with 40 nominal horse-power engines for the Humber; and two for the lakes of Zurich and Wallenstadt in Switzerland, which, after being tried, were taken to pieces and sent out.

In 1831, Dr. Fairbairn built the "Manchester," of 70′ 0″ × 15′ 0″ × 8′ 0″, with engines of 30 horse-power; in 1832, "La Reine des Belges," of 75′ 0″ × 14′ 0″ × 6′ 0″, with engines of 24 horse-power, which went from Liverpool to Ostend. In 1833, he built the "Minerva," of 98′ 0″ × 15′ 6″ × 7′ 0″, with 40 horse-power; which boat was sent in pieces to Hull, put together, and made the voyage to Rotterdam in thirty-three hours, and then steamed up to the Rhine Falls, where she was again taken to pieces and carried overland to Lake Zurich.

The difficulties which were found to exist in an inland town like Manchester for the construction of iron vessels led to the removal of this branch of the business to London in the years 1834-5, where, at the works, Millwall, Poplar, Dr. Fairbairn constructed upwards of eighty vessels of various sizes, including the "Pottinger," of 1250 tons and 450 nominal horse-power, for the Peninsular and Oriental Company; the "Megæra" and other vessels for the British Government, and many others; thus introducing iron shipbuilding on the river Thames; and in 1848 he retired from this branch of his business.

In 1835-6, the well-known firm of Messrs. Ditchburn and Mare commenced iron shipbuilding on the Thames, which they carried on for many years in Bow Creek, the site of the present Thames Iron Works, and at a later period were followed by Messrs. David Napier, Samuda Bros., M. and H. L. Wigram, Miller and Ravenhill, Robinsons and Russell (afterwards the well-known firm of J. Scott Russell and Co., who built the "Great Eastern," and whose premises included those formerly occupied by Messrs. Fairbairn and Napier), Joyce, Dudgeons, Rennie, and others.

In 1831, an iron steamer called the "Fairy Queen" was built at Glasgow by John Neilson, of Black Quarry and Oak Bank, which was taken from the building-yard to the Clyde on a truck, and launched broadside on into the river, in a more successful manner than was the case with the "Great Eastern" at a later period on the Thames. Her dimensions were as follows:—Length, 95′ 2″; breadth, 11′ 5″; depth, 8′ 2″; $39\frac{75}{94}$ tons register. In 1834 she was lengthened.

In 1832-3, Messrs. Thomas Wingate and Co., of Whiteinch, near Glasgow, built at Springfield an iron lighter, which was taken to Port Eglinton, and launched in the Paisley Canal. This firm, in the year 1837, put a pair of side lever engines, with 60″ × 6′ stroke cylinders, into the wooden steamer "Sirius," of 700 tons; the first steamer that ever crossed the Atlantic.

In 1834, Mr. David Napier built the iron steamer "Kilmun," of 119′ 7″ × 15′ 5″ × 8′ 5″ = 144 tons, with engines of 70 horse-power, which plied between Glasgow and Kilmun.

In the same year, the "Swan," of 10 horse-power, with engines by James Gray, of Glasgow, was built by John Neilson, to ply between Londonderry and Strathbane.

In 1835, Mr. David Napier built the "Loch Lomond," to ply on the loch of that name. She was 92′ 9″ × 15′ 1″ × 7′ 0″ = 76 tons, with engines of 40 horse-power.

In the same year, Messrs. Tod and McGregor built the "Vale of Leven," to ply between Glasgow, Dumbarton, and Greenock. She was 93′ 1″ × 16′ 5″ × 7′ 6″ = 121 tons, with engines of 51 horse-power. The "La Plata," with two horizontal engines of 10 horse-power, was this year built at Johnstone, and engined by Tod and McGregor.

In 1836, Mr. John Neilson built the "Maid of Claro," for Yarmouth. She was 56′ 1″ × 9′ 8″ × 7′ 1″ = 35 tons.

In the same year, Messrs. T. Wingate and Co. built the "British Queen," to ply between Glasgow and Garelochhead. She was 125′ 4″ × 16 5″ × 8′ 5″ = $144\frac{70}{100}$ tons, with steeple engines of 90 horse-power.

Messrs. Tod and McGregor also built in this year the "Royal Tar," to ply between the same places, and the "Express" also, which plied to Kilmun besides. The "Royal Tar" was 125′ 7″ × 16′ 6″ × 8′ 8″ = 141 tons, with engines of 80 horse-power; and the "Express" was 130′ 4″ × 16′ 4″ × 8′ 5″ = 150 tons, with engines of 94 horse-power. They also at the same time built the "Shamrock," of 116′ 1″ × 16′ 3″ × 9′ 2″ = 160 tons, with engines of 77 horse-power, to ply between Waterford and New Ross; and Mr. John Neilson built the "Egremont," of 87′ 7″ × 17′ 4″ × 8′ 2″ = 129 tons, with engines of 70 horse-power.

In 1837, Messrs. Tod and McGregor built the "Benledi," to ply between Leith and Dundee. She was 124′ 5″ × 15′ 9″ × 8′ 6″ = 102 tons register, with engines of 77 horse-power; and the "Rothsay Castle," to ply between Glasgow and Rothsay. This vessel was 133′ 8″. × 17′ 0″ × 8′ 6″ = 180 tons, with engines of 90 horse-power.

In the same year, Messrs. T. Wingate & Co. built the "Loch Lomond," for Dumbarton. She was 101′ 8″ × 16′ 5″ × 8′ 5″ = $77\frac{43}{100}$ tons register, and had steeple engines of 52 horse-power.

In 1840 this vessel was sold to some parties in Hamburgh, and used to ply on the Rhine. In the same year they built the "Prince Albert," for Liverpool, which was 107′ 6″ × 16′ 5″ × 8′ 1″ = 122 tons, with engines of 60 horse-power.

Messrs. Smith and Rodger the same year constructed a double cigar-ship called the "Victoria," which consisted of two cigars, 92′ 8″ × 7′ 0″, set side by side, and a hurricane deck, with a paddle-wheel in the centre propelled by engines of 75 horse-power.

In 1838, they built the "Plenipo," to ply between Glasgow and Kilmun. She was 118′ 5″ × 15′ 7″ × 7′ 2″ = 113 tons, and had steeple engines of 65 horse-power.

Messrs. Tod and McGregor in this year built the "Royal Sovereign," to ply between Glasgow and Liverpool. She was 177′ 5″ × 21′ 2″ × 12′ 1″ = 446 tons, and had engines of 220 horse-power.

After this date, iron paddle-steamers were built in rapid succession; but screws did not come into general use as cargo-boats till after 1845.

So far as the author can find, transverse water-tight iron bulkheads in *iron steam*ships were introduced by the late Mr. Charles Wye Williams, who first employed them in the "Garryowen," iron steamer, in (it is said) the year 1833-4. Transverse bulkheads made water-tight in wooden ships were introduced in this country by Captain Shanks, about the year 1790, in a vessel called the "Trial," and used by Sir Samuel Bentham, K.S.G., in his seven experimental vessels designed in 1794. Longitudinal bulkheads were introduced by Sir Samuel.

In 1838, a Mr. Wheelwright, of Regent Street, London, brought forward the "longitudinal" system of construction, which has since been brought to such perfection by Mr. Scott Russell in the "Great Eastern," and numerous other vessels designed and constructed by him before and since, and has given very satisfactory results in practice. This is manifestly the proper way of making a ship of great strength, instead of using the ordinary vertical angle, iron frames which give no strength in a longitudinal direction. Mr. Wheelwright published a small pamphlet on this plan in 1838, which was accompanied by plans and sections, and it may be seen in the library of the Institution of Civil Engineers.

The first iron sailing-vessel built in Liverpool was the ship-rigged vessel "Ironsides," of 248 tons register, which was built by Messrs. Jackson and Gordon, for Messrs. Watson Bros., and launched in October, 1838.

In 1840, Messrs T. Wingate and Co. built the first iron sailing-vessel constructed in Scotland. She was called the "Henrietta," and was 57′ 8″ long × 16′ 5″ beam, × 7′ 4″ deep, = $61\frac{68}{100}$ tons.

In 1840-2, Messrs. R. Saunderson and Co. built the "Vulcan," of 63′ 0″ × 14′ 4″ × 9′ 0″, and the "Cygnet," of 60′ 4″ × 18′ 0″ × 10′ 1″, which were employed in the trade from Leith to Rotterdam; and in 1841, Messrs. Anderson and Gilmore, of Govan, built the "Waterloo," of 78′ 8″ × 20′ 0″ × 9′ 0″, which traded from the Clyde to the West Indies.

In the year 1839-40, the first iron steamer for the Royal Navy, the "Dover," was built by Messrs. Laird, of Birkenhead; and about 1843, the British Government began to extend their employment of this material.

In 1841, the "Great Britain," iron-screw steamer, of 3500 tons and 1000 nominal horse-power, was commenced at Bristol. Her dimensions are as follows:—Length over all, 320′; beam, 51′; depth, 31′ 4″; and the lines were designed by Mr. Paterson, of Bristol. This vessel was launched in 1843, after a great expense and trouble in enlarging dock-gates, &c., to get her through (reminding one of the story of Robinson Crusoe and his "big boat"), had been got over; she made several voyages to America, and having been run ashore on the coast of Ireland, where she passed through the storms of a very severe winter, was finally got off, taken to Liverpool, and having undergone alterations in engines, boilers, and fittings, was placed on the Australian trade, where she still remains, and is known as one of the most regular and successful ships in that employment.

In 1854, the construction of the "Great Eastern," paddle and screw combined, was commenced at Millwall, London, by Messrs. J. Scott Russell and Co. The length of this vessel on deck is 692′ 0″, her beam 82′ 6″, and depth 58′; tonnage, B. M., =24,360 tons; paddle engines, 1000 nominal horse-power; screw engines, 1600 nominal horse-power. The lines of this vessel were designed by Mr. Scott Russell, and the ideas on which a ship to fulfil the conditions proposed to be accomplished by the company, which was got up to construct her, were promulgated before 1838 by a Mr. Holmes, and in 1840 by Lieut. Radford, R.N., the latter of whom published a small work on the subject, in which nearly all the advantages and reasons for the construction of such vessels as the "Great Eastern," which were brought forward at a later period, were fully entered into.

It is recorded that when Mr. Holmes first broached this subject at the Admiralty and elsewhere, they laughed at the idea, and begged him to desist from pursuing so futile a plan.

The "Great Eastern" was built "broadside on," with her bow down the river, and the first attempt at launching her was made by Mr. I. K. Brunel, the company's engineer, on a new plan invented by him, on the 3rd November, 1857, but resulted in a total failure. The reason of this was, that instead of employing greased wooden ways, the experiment was persisted in of launching on iron rails, the cradles having bars of iron placed transversely to the longitudinal Great Western rails under them. The great friction and bite of the iron on iron, and a deficiency of bearing surface on the ways when the ship had moved from the thickly piled surface on which she had been built, brought everything to a dead lock; and it was only by the employment of some twenty-two of the most powerful hydraulic rams or presses which could be obtained, including those used to lift the Britannia tubular bridge, that the ship was pushed by main force into the river and floated off on the 31st January, 1858, after many weeks' almost constant exertions, both night and day, and the expenditure of an unknown number of thousands of pounds.

It is worthy of note that, although this huge vessel remained on the ways with some 140 feet at each end hanging in the air, and totally unsupported for a period of three months all but three days, it was found, when her sheer was tried after she was afloat, that the change in her length of 692′ 0″ could be expressed by the fraction of an inch! It is to be regretted that the want of proper management should have hitherto prevented the capabilities of this vessel from having been properly and thoroughly developed, but so far it would seem that, for weights moved, and power or force expended in doing it, at the same speed as other vessels of a large class, she will bear a very favorable comparison; and the success attending the laying of the Atlantic Telegraph cable by her means is sufficient almost to have justified her construction specially for this purpose.

In 1854-5-6, during the war with Russia, the British Government built several wooden floating batteries of 1469 to 2000 tons, cased or plated with rolled iron four inches thick, and provided with high-pressure engines of 150 to 200 nominal horse-power, driving the screw propeller. These vessels were introduced by the Emperor of the French.

In 1859 the first *iron* ship, *plated* with rolled iron 4½″ thick, the "Warrior," of 6038 tons, and 1250 nominal horse-power, was laid down by the British Government, and launched in 1861. Her length is 380′; beam, 58′; depth, 42′.

Since this period the iron-built iron-plated vessels have been increased in size, some being 6621 tons and 1350 nominal horse-power, with a length of 400 ft. and a breadth of 59 ft., with armour 5½″ in thickness, such as the "Minotaur," the "Agincourt," and "Northumberland."

Besides these are numerous smaller vessels of 3700 tons, down to vessels of 700, both sizes carrying 4½″ armour plates; and the "Hercules," "Monarch," "Captain," and "Penelope," will have armour plates of 8″ and 6″ in thickness.

It is said that designs are now prepared for iron vessels of 10,000 tons, with 62 guns on two decks, and iron armour of 5½″

thick, in which no teak or wood backing is to be used, and their length is to be over 400 ft.

In the year 1838 the Committee of Lloyd's Register classed the first iron vessel that had ever been guaranteed as "fit for the safe conveyance of dry and perishable cargoes." "This barque was appropriately named the 'Ironsides;' she was 271 tons register, was built at Liverpool by Messrs. Jackson and Gordon, for Messrs. Cairns and Co. She was launched on 17th October, 1838, and was built of angle iron and plate iron, much in the same manner as iron ships are now built. She performed her first voyage to Rio de Janeiro and back without damaging any cargo. She was classed by the Committee of Lloyd's Register, after careful consideration, on the 15th November, 1838, as 'built of iron,' with no letter. From this date until 1844 the Committee of the Register Book continued to class iron ships by the designation 'built of iron,' but with no letter."

From 1844 to 1854 the Committee improved the classification by marking them A 1, "built of iron," but this character was limited to six years. However, before the termination of this six years' classification the number of iron ships had so increased, and the demands for some kind of higher class based on admitted rules was so general, that the Committee of Lloyd's Register considered it necessary to form a code of rules for their own guidance and for that of the builders of iron ships; but having in vain solicited the assistance and concurrence of the iron shipbuilders throughout the country to form such rules, they in 1854 appointed a select committee, composed of members of their board more conversant with shipbuilding, who, with the assistance of their own surveyors (by collecting the scantlings of iron ships already classed), compiled their celebrated 'Rules and Tables of Scantlings' for ships of six, nine, and twelve years' grade, and which, when confirmed by the general committee, was prefaced as follows:—"Considering that iron shipbuilding is yet in its infancy, and that there are no well-understood general rules for building iron ships, the committee have not deemed it desirable to frame a scheme compelling the adoption of a particular form or mode of construction, but that certain general requirements should be put forward having for their basis thickness of plates and substance of frame, showing a *minimum in each particular* to entitle ships to the character *A* for a period of years, subject, however, to certain periodical surveys, and also to a continuation of such character should their state and condition justify it on subsequent examination."

Although the mode of constructing iron ships primarily intended by these rules is the original and ordinary one of vertical frames and longitudinal plating, the committee do not hesitate to admit into the Register Book, and into the same classes, vessels otherwise constructed, if of equal strength, and have classed ships with longitudinal frames or with diagonal frames, and many with double or cellular bottoms for water ballast, &c.

Thus, by wise and practical rules, administered with even-handed justice and impartiality, has this important society striven to assist the shipbuilders and shipowners of this country to improve the merchant shipping of Great Britain and her colonies, and are reaping a well-merited reward in the general improvement of the structure of ships, and in the increasing confidence reposed in them by all parties interested in shipping, having never had at any time so many vessels building in conformity to their rules, under the special supervision of their surveyors, as at the present moment.

The endeavours of this committee have been directed to carry into effect as far as possible a uniform system of construction, which shall, in all essential points, secure strength of hull, wise disposition of material for economy, provisions for the safety of life and property, and durability; to encourage and not to retard the introduction into naval architecture and shipbuilding of every real improvement in the mechanical structure of ships that may better adapt them to the special object they may have in view. The rules allow the classification of a ship of good material, of sound workmanship, and of skilful design, to take rank according to her intrinsic qualities, in whatever manner those good qualities may have been achieved.

The author begs to return his best thanks to Dr. Fairbairn for the valuable information he has afforded him regarding the origin of iron shipbuilding on the Thames; to Messrs. Laird Brothers, John Laird, Esq., M.P., and Mr. C. B. Bean, of the 'Liverpool Albion,' for the same respecting the town of Liverpool; and to Messrs. T. Wingate and Co., engineers and iron shipbuilders, of Whiteinch, near Glasgow, for that relating to the Clyde.

To his applications for information respecting iron ships on the Tyne and the east coast, the author has not received any replies, and has been unable to collect any particulars on this part of the subject.

In conclusion, he would say that he will be glad to receive authentic information, facts, and dates, relating to the early history of iron ships and boats, for use in future editions, and will esteem it as a favour if any of his readers who can, will kindly take the trouble to supply him with such information as they may possess or obtain on the subject.

# CHAPTER IV.

## SHEATHING.

The protection of the submerged portions of a ship's hull, and the necessity of it, whatever material the ship may be constructed of, seems to have been long acknowledged and practised. The materials employed for this purpose are almost innumerable, and we find wood, copper, lead, zinc, porcelain, Roman cement, Portland cement, leather, tin, yellow metal, india-rubber, tinned iron, woven metal and vegetable fabrics, brass, glass, plaster, &c. &c.; in fact, it would seem that almost everything had at one time or other been pressed into the service.

Atheneus, quoted by Ewbank, informs us that the ship of Archimedes was fastened everywhere by *copper* bolts weighing ten pounds each and upwards, whilst the *bottom was sheathed with lead.*

Lead was used as a material for sheathing in the second century, for Alberti tells us, in his work on architecture, which was published in the fifteenth century, that whilst he was writing that book a ship, called "Trajan's Ship," was raised from the bottom of Lake Riccia, which had been submerged for above 1300 years, and that "over all there was *lead* sheathing fastened on with little *copper* nails."

A boat, thirty feet in length, was found in the fifteenth century sunk in the Mediterranean in twelve-fathoms water, which had the deck covered with paper and linen, and sheets of lead fastened with gilt nails over all; and when stripped off, parts of the covered portion were found quite dry, the boat being estimated to have been 1400 years submerged. The hull was of cedar and larch.

A Roman ship sunk in the Lake of Nemi was found to have been coated with bitumen, over which sheets of lead had been nailed with gilt nails. The seams of this vessel were caulked with tow and pitched, the material of the hull being larch.

In the reign of Henry VIII large vessels had a coating of loose animal hair attached with pitch, over which a sheathing board of about an inch in thickness was fastened, "to keep the hair in its place." It seems, however, that sheathing the hull or building another over it was not approved of by these early navigators, and in 1668 the officers of the fleet fitting out under Sir Thomas Allen to attack the Algerians petitioned that they might not have their vessels "so encumbered," as they "were always unable to overtake the light-sailing unsheathed vessels of the enemy." This petition was granted on condition that the ships' bottoms were cleaned very frequently.

In the reign of Charles II the "Phœnix" was sheathed with lead, and soon after about twenty ships were so sheathed, milled lead fastened with copper nails being used.

In 1667, during the same reign, it is noted "that wee and divers of our subjects are att great charges in the sheathing shipps for the streights and other foreign parts." For many years, and up to the middle or latter end of the last century, the sheathing generally in use seems to have been a doubling of the skin of the ship with wood, which was kept constantly payed over with tar, grease, or a mixture of these compounds. The writer of these pages remembers a small schooner which was so constructed, and after some time had a sheathing of copper or yellow metal laid on this wooden sheathing.

In 1670 a patent was granted for the use of milled lead for sheathing, and it was ordered that "no other than milled lead sheathing should be used on His Majesty's ships." In the year 1700 lead was acknowledged to have proved a failure, and the use of wood sheathing was again resorted to.

In 1677 and 1678 Sir John Narborough and Sir John Kempthorne complained that the rudder irons of the "Plymouth" and "Dreadnought" were so much eaten as to make it unsafe for them to go to sea; and in 1682 similar complaints were made of the effects of lead in contact with iron.

In the year 1682 a commission was appointed to investigate the subject, and the result was that lead sheathing was abandoned. In the latter half of the last century, however, the "Marlborough" was sheathed with lead, and laid up in ordinary at Sheerness. In a few years after, or in 1770, she was docked at Chatham, and it was found that the lead had eaten away the iron fastenings very considerably, in consequence of which the lead was stripped off, and wood sheathing substituted.

Alloys of lead have also been tried, but all produced similar results, and were consequently abandoned.

Lead stands next to copper in its galvanic action on iron, and although it is far cheaper than copper, still its injurious effects, and the trouble, complication, and expense, necessary to insulate it, preclude its use as a material for sheathing iron ships.

In 1687 a patent was obtained for using rollers to mill lead into sheets, "as well for the sheathing of ships as for any other use or purpose whatsoever," and in 1728 another patent was obtained for a "new method of sheathing and preserving the planks of ships." This consisted of "rooled copper, brass, tin, iron, or tinned plates." In 1779 was patented a "compound metal capable of being forged when red hot or when cold, more fit for making bolts, nails, and sheathing for ships, than any metals heretofore used." This was a very close approach to Muntz's metal. In 1800 was patented "red, yellow, and white sheathing," consisting of various mixtures of copper, zinc, and tin. This was again a near approach to Muntz's metal. In 1805 the manufacture of zinc into sheathing for ships was patented.

From this period numerous patents were obtained for materials or their mode of application in sheathing vessels, such as electrotyping the whole hull, and various other contrivances, most of them exhibiting an utter disregard of chemical knowledge, such, for instance, as that of Mr. J. E. M'Connell, who in 1852 proposed to apply sheets of brass or copper directly to the hull of the vessel and riveted thereto, without the interposition of any insulating material, galvanic action being thus set at defiance! Others, again, proposed to sheathe the iron hull with wood, to which the metal sheathing may be applied, as in a wooden ship; and then, again, various nostrums against fouling and corrosion are patented, such as glass, phosphorus, arsenic, &c., all of which are either so absurd or worthless as not to need further attention.

Sheathing or protecting the hulls of iron ships comprehends the following points:—Materials used, mode in which they are applied, principles involved in their action, their advantages or disadvantages, cost, durability.

The materials used have been metallic or non-metallic. The disadvantages of the metallic are that, unless carefully selected with reference to their action on the iron hull of the ship, they give rise to one or all of the following serious objections:—They do not fail to set up a serious destructive galvanic action with the hull of the ship, and thus become rapidly foul, at the same time dooming the hull to certain destruction, and their application has been a complicated and unsatisfactory process. They are not readily applicable to an iron ship, unless she be specially constructed for the purpose of being sheathed, with facilities for attaching the plates.

The non-metallic sheathing is either in the form of a paint and smeared on, or else laid on, plastered or spread as a paste or mortar, or stuck on by means of some adhesive glue or other medium. As the adhesion is merely that of plaster on a wall, and is influenced by wet, damp, or the state of the atmosphere when being laid on, and it cannot be attached with such a degree of firmness as can be done with sheets of metal, none of them are calculated in any way to fulfil the prime requirements of the case, viz. the complete protection of the hull from the action of the sea-water, and causing the action of that sea-water to induce a constant renewal and cleansing of the surface, whereby alone fouling can be prevented and the corrosion of the hull avoided. Not even the "enamelling," which is so beautifully done, is of the slightest use, as it presents a *permanent* surface, and does not exfoliate; besides which the difference of expansion of the iron of the hull and the enamel causes it continually to chip off. Most of the plans for sheathing or protecting the hulls of iron ships seem to have been originated with the view of their application to ships *already constructed*, and until 1863, when Mr. T. B. Daft, C.E., patented his improved plan of constructing ships, so as to admit of their being readily sheathed, this point seems to have been overlooked. In order to apply sheathing to ships already built, it becomes needful to attach a coating of wood, to which this sheathing is to be nailed, and the difficulty they all labour under is that they are *not* component parts of the structure of the ship, but are, as it were, plastered on to the hull, and consequently easily damaged and readily detached.

By the plan of Mr. Daft the hold for the sheathing nails is incorporated in the body of the vessel, and thus becomes a part and parcel of it, placing the vessel and her sheathing in the same position as a coppered wooden hull, exposed to similar casualties in regard to stripping, &c. This plan increases the facilities for sheathing, decreases the expense, and does not increase the bulk of the hull by more than the thickness of the zinc sheathing used for the purpose, besides making a flush surface, and a better job in all respects.

Wood sheathing on the hull of an iron ship is a mistake. It is of no use to prevent fouling; it does not strengthen the ship; it becomes water soaked; it enlarges the midship section, and consequently does not increase the ship's speed; it is sure to be quickly attacked and destroyed by worms; in fact, it can only be at once and unhesitatingly condemned, more particularly when it is accompanied with the pernicious arrangement of sheet copper or yellow metal laid on it.

The cost of this complicated arrangement, viz. first giving the ship a coating or two of red lead, marine glue, cement, or some other delightful material, then a coating or sheathing of felt or india-rubber, or both combined, then a coating of wood, and then the sheathing of copper or yellow metal, is no small trifle, the "Royal Sovereign" being estimated to cost £3000, which may be looked on as thrown entirely away, first, because the plan is inefficient; secondly, because it brings in the fatal objection of galvanic action; and thirdly, because it is eminently lacking in solidity and durability—points that should never be lost sight of in carrying out such undertakings.

Zinc as a material for the sheathing and protecting of ships' bottoms is a comparatively new application in this country, for it seems that, though patented in 1805, in 1848 there were only five British ships on which it was known to be employed. So well did it answer, however, that by the year 1850 there had been 300 ships sheathed in British ports, which number had increased in 1852 to upwards of 1000, and its increase still appears to be great. All these vessels were of wood, however, and it was specially requested that in applying this material to ships fastened with copper, yellow metal, or iron bolts, layers of tarred felt should be placed over them to prevent galvanic action destroying the zinc.

Zinc rolling mills seem to have been first started in the year 1834 at Dartford, in Kent, the machinery being made by Hall, the well-known engineer of that place.

So little was the action of sea-water upon the copper or metal sheathing of a vessel understood, that it was believed and asserted to have kept clean by the oxide poisoning the zoophytes, &c., which adhered to it; and when after some time the copper sheathing of our ships of war was found to wear out, it was assumed that this action ought to be stopped, and accordingly Sir Humphrey Davy was applied to to introduce some mode of removing this evil.

For this purpose he arranged iron "protectors" in connection with the copper, which were applied to the "Magicienne," and it was found that this plan only gave local protection, the greater part of the copper oxidising as usual, only the parts contiguous to the protectors being protected, and these portions were covered with barnacles. These experiments, when carried further by means of plates of tin, zinc, or other easily oxidizable metal, applied to coppered ships, gave so perfect a protection that the ships' bottoms became covered with barnacles and weeds, thus introducing a far more serious evil than the one it was desired to remedy. It would have been thought that these facts would have afforded excellent grounds on which to form a theory of the mode in which copper sheathing operated in removing fouling, and to have led to a serious consideration of the subject; but it seems not to have excited any attention, and the poisoning theory continued, and still remains in force in some cases at the present moment.

There can be no doubt that, had proper attention been given to the chemical action of metals in contact with sea-water, we should not meet with the constant reference to the destructive action of corrosion in our iron-clads and other iron ships, which so constantly appear in the columns of the daily press, nor would there have been the enormous expense we now have to encounter from the fouling of our large iron ships, and their consequent docking, cleaning, painting, &c., and loss of time involved thereby, as due consideration must have led to the devising of some practical mode of construction and sheathing by which all this would have been obviated.

At the present moment this question is little understood by many, and some have even gone so far as to compound a mixture to be smeared over the copper, yellow metal, or zinc sheathing of ships, to prevent the very action by which it keeps free from fouling, namely, exfoliation! and advance as an argument in its favour that it will not wash off, and it completely arrests the oxidation or wear of the sheathing, stating that the full weight of the metal sheathing will be returned whenever it may be taken off, and recommend its use on account of the immense saving that it would effect.

Now, on analysing the subject and its economical results, the following particulars are obtained:—First, a ship is sheathed with copper, yellow metal, or zinc, in order that the loss of speed and fouling found to ensue if they be not used may be prevented by their exfoliation, and the hull saved from the attacks of worms. Second, in order to prevent the copper exfoliating, and thus keeping clean, and also the waste caused by that exfoliation, a mixture or compo' is smeared all over the copper. Third, this mixture or compo' is said to prevent fouling and oxidizing, and also to prevent the attacks of the worm. Therefore it follows, if this be true, that the compo' will do all that the metals can, and that consequently any metal sheathing is unnecessary.

Against any advantage that may be claimed for paints, compo', &c., must be set the certain fact that they do not remove the necessity for frequent docking, cleaning, and repaying, or plastering, with all their accompanying delays, expenses, and drawbacks; and it is certain that whatever weight of copper or other metal sheathing they may prevent the waste of, over a period of say three or four years, if their application be continued so long, it is equally certain that the use of this protective compo', its docking, renewals, and other expenses, will be found to far exceed any possible saving that might be effected, and, in fact, to be more than the cost of recoppering or sheathing the ship at the end of such a period.

It is now a decided fact that no material which presents and maintains a *permanent surface* is of the slightest use in preventing fouling or corrosion. The general ignorance of the action of copper sheathing in keeping clean has caused the continuance of the evil, and perpetuated a host of nostrums of the most expensive, useless, and troublesome description, without in the slightest degree abating the nuisance, added to which it has introduced and encouraged the useless and highly dangerous plan of placing sheet copper or yellow metal on iron hulls, for no other reason than because they have been used, and keep clean on wooden hulls; and this too, in defiance of all that is known in regard to galvanic action, its causes and results. Did any individual shipowner choose to experiment on the readiest and surest way of destroying his own iron fleet, there would not be much said about it; but when such absurdities are carried out on a national fleet, on which millions have been expended, and in which all are interested, it then becomes a very serious matter.

There can be little reason to doubt that the constant advocacy of copper or yellow metal as the only proper material for the sheathing of iron ships arises from an ignorance of the action of it in preventing fouling, it being almost the universal opinion that the "poisoning" process is what causes it to keep clean. That the poisoning theory is a fallacy the success of zinc (which is admitted to be non-poisonous) when applied to iron, in keeping free from fouling, sufficiently proves; and where the mechanical assistance to the process, viz. the friction caused by the ship in passing through the water, which aids in rubbing off the exfoliation, does not take place—for example, when the ship lies at her moorings—a limited degree of fouling still takes place on the surface of the copper or yellow metal, in spite of sufficient verdigris or poisonous matter being on the surface, to give ample proof whether the theory be right or wrong.

The action of copper in keeping clean is thus stated by the 'Engineer' of December 21st, 1866:—"The beneficial action which continuously keeps a copper bottom from sea-weed is evidently due to a double process of exfoliation and of a generation of a poison (verdigris) inimical to the development of organic life."

The idea of copper keeping clean by the poisoning process killing the zoophytes was held by Sir Humphrey Davy, and in order to prevent what was then considered the unnecessary waste of copper sheathing, by corrosion or exfoliation, he protected it by zinc or iron. The experiment succeeded scientifically and thoroughly in preventing exfoliation or loss; but it failed to be a practical benefit, inasmuch as the sheathing became covered with sea-weed, shell-fish, &c., which it did not do when the copper exfoliated, consequently his plan had to be given up, to the great mortification of Sir Humphrey.

If this idea of poisoning the weeds, barnacles, polypi, and other annoyances which seem to have such great "proclivities" for ships' bottoms, were correct, there can be no doubt that such action would take place just as surely and well whether the ships were at anchor or under way; and there would not then be found the constant records of the failures which greet all the multifarious attempts which have been and are yet made to obtain success by this process, whether sought for by the application of compositions, plasters, or by the application of the metal in sheets.

The fallacy of the "poisoning" theory will be proved further on in this work from the results of actual experiments; and it is well known that all the "compositions" compounded in accordance with this theory have totally and utterly failed when tried in actual use.

It is a curious fact, that but little attention has been given to investigate the action required in whatever is used as a means for preventing the fouling of ships' bottoms; but it has at once been assumed that the action required is that of poisoning, and on this hypothesis nearly all the inventors have proceeded. The results will be found recorded in the chapter on Fouling.

It was stated at a late meeting of the Scottish Shipbuilders' Association, by the chairman, that an iron plate had been coated in squares with four of the best-known "anti-fouling" compositions, and, after having been submerged for some months, was raised for examination. The plate was found covered with barnacles, and the most ridiculous part of the affair was that the biggest barnacle of the lot, "the great grandfather of all barnacles," had stuck himself in the very centre of the plate, right on the point where all the four compo's joined, as if to show his utter contempt for and ridicule of the useless and worthless plan of "poisoning" them.

The royal mail-steamer "Atrato" had one side coated with a preparation of copper, its use being propounded in accordance with the "poisoning" theory, and when docked for examination the green copper composition was found to be covered with a coralline incrustation and patches of rust or oxide.

The "Valiant," in 1865, had one side coated with a preparation of copper, and when examined, in about five months afterwards, was found to have this "poisonous" composition thickly coated with barnacles, sea-weed, &c.

The "Orontes," iron troop-ship, was coated with a poisonous anti-fouling composition containing copper, and when examined some time afterwards was found to be, under her counter and in the run of her after portion of the hull, thickly encrusted with barnacles; and the bottom was dotted all over with patches of rust, the rivet-heads in many places showing evident signs of being affected by the copper contained in the anti-fouling composition.

In the 'Times' of January 17th, 1865, it was stated that the "Royal Oak" iron-clad, which is sheathed with Muntz's metal, was docked, after *six months'* service, in the Mediterranean, and "her bottom was found to be foul beyond conception; masses of animals, zoophytes, corallines, &c., all so encrusted with weeds in one mass that sharp scrapers will alone detach them."

It is stated that one of H. M. ships, which had been lying quiet at Bermuda for some time, had layers of oysters, &c., upwards of a foot thick, on her copper sheathing, the copper being actually taken up by the animal in the formation of its shell as a carbonate of copper, the shells of the inner layer of oysters being all of this beautiful green colour throughout. Some of these shells were a short time since in the possession of the storekeeper of the Royal William Victualling Yard at Plymouth.

In another case the interior of one of the large globes of Griffith's screw propellers, which in the navy are made of gun-metal, was found on examination to be completely filled up with full-grown mussels and barnacles, although the aperture through which the spawn had entered was not more than half an inch in area. Where, then, is the "poisoning" theory in all these instances?

The French Government seems to maintain a perfect indifference to the fatal injury resulting to the iron hulls and armour plates of the iron-clads from the use of copper or yellow metal sheathing, in spite of the remarks of M. Becquerel, their eminent chemist, whose researches have shown that, by the employment of zinc for sheathing iron vessels in place of copper or yellow metal, the iron may be kept free from fouling, and also preserved instead of injured, which is of the greatest importance.

It is curious to see the constant and persevering attempts which are made, both in England and France, to use copper or yellow metal for sheathing iron ships, and the schemes which are tried to prevent its certain and fatal action, whilst any endeavour to give zinc an equal trial is most studiously avoided. It would seem as though there were some fascination, or important advantage to be gained by trying the former, which does not exist, or has not been discovered in the case of the latter. But it remains to be seen whether the tax-paying public will much longer permit these useless and dangerous experiments to be tried on the costly iron-clads.

M. Roux, a captain in the French Imperial Navy, seems to have succeeded in convincing the naval authorities of that country that copper can be readily applied to iron hulls without causing any damage! It is stated in the 'Engineer' of December 21st, 1866, that "It was M. Dupuy de Lôme who first suggested to Captain Roux the idea of applying copper directly on the iron shell of the vessel, observing that the effects of any galvanic current were not to be feared, 'as long as the plan employed absolutely prevented the presence of sea-water at the points of contact of the two metals.'"

The same journal goes on to say that "The next steps were, therefore, to find a mode of isolating the copper from the iron, and some mechanical plan for securely fixing the copper sheets." In order to obtain the former, it is said that he coats the iron with red lead, over which he places a composition, and on this composition he places the copper. For the latter, viz. "a mechanical plan for securely fixing the copper sheets," it is stated that the inventor "professed to drill into the iron a small conical hole five millimètres deep and six millimètres (about $\frac{1}{4}$ inch) in diameter, and then to spread out a suitable rivet in this hole. By this means any defects resulting from the drilling of the hole practically disappeared, the soft rivets completely filled up any irregularities, and were firmly clenched in."

Of this plan the 'Engineer' remarks, "It is certain that the process has a simple and rational look, whatever may be the ultimate results."

Now, there are generally about 120 holes in a sheet of copper as used for sheathing wooden ships, and a ship of 400 tons generally requires 1140 such sheets. If, therefore, the same proportion holds good for iron ships, it follows that the amount of holes drilled into the hull for the reception of the "soft rivets" will amount to something considerable (in the case of a 4000 ton ship, on one plan of sheathing, there are 45,663 holes at 3d. each = £570 15s. 9d.); but as it is *only* "drilling holes," there can be no doubt of the "simplicity" of this part of the process.

It will be interesting to examine the mode in which the experiments with Captain Roux's plan were carried out, from which sufficient results were obtained to satisfy those in authority of its feasibility and advantages, and also to prove to them that the destructive action of copper on iron does not present any real difficulty in actual use.

We are told that the "first trial was made with a large flat-bottomed iron boat, the plates of which were very much corroded. After a service of nine months at sea, seven of which were passed in active service at the arsenal of Toulon, the boat was taken on land and examined by a commission and M. Dupuy de Lôme. No vegetation was found on the outside, and only one copper sheet above the water-line was found injured, probably by scraping against another vessel; on stripping more of the copper sheets the iron was found in a perfect state of preservation, without oxidation, and all the rivets in a good state."

We are further told that, "in consequence of this success, the iron-plated *corvetice* 'La Belliqueuse' was placed in M. Roux's hands to be sheathed by his process before beginning a long cruise in the Pacific. He expects that the copper sheathing will last twelve years, as his plan is based upon the principle that the copper protects the composition, the composition the red lead, and that, lastly, the red lead protects the iron." Since the sheathing of "La Belliqueuse," M. Roux has been ordered a few weeks ago to apply his sheathing to the iron-plated frigates "La Savoie" and "La Revanche."

A few moments' reflection will show how insufficient such a plan of trial is, and how well calculated to cause error. The boat, we are told, was "seven months in active service at the arsenal at Toulon;" when she was hauled up and examined the iron was found "in a perfect state of preservation, without oxidation."

Now, here were conclusions drawn from the results of circumstances which never exist in the case of large ships in active service, and it does not seem that it ever occurred to any one that this was the case. This flat-bottomed boat, we are told, was coppered "above the water-line; she was employed at the arsenal at Toulon," and consequently in smooth water, not being subjected to the constant washing of the water over the copper and the iron hull, as would be the case of a large ship at sea in active service, and which it is found wholly impossible to prevent.

It is this contact of the water with the copper or yellow metal and the iron hull which causes the destructive galvanic action to be set up. Keep the three from contact and no result follows, but it matters not how perfectly or completely insulation may be secured between the iron hull of the ship and the copper sheathing by the interposition of non-conductors, if when the ship is afloat the water is allowed to produce contact between them by washing indifferently over both.

It has actually been proposed to drill the skin of an iron ship full of holes, and *tap* copper bolts or studs into them with the view of riveting on copper or yellow-metal sheets, interposing a sheet of iron and some insulating material between; and it is gravely asserted that this will prevent the water following or obtaining access to the skin of the ship, and thus prevent the corrosion and galvanic action between the different metals and the water which would otherwise take place!

This ingenious, cheap, and thoroughly practical arrangement, which is perfectly in accordance with the knowledge required to devise an arrangement to set up galvanic action to destroy the positive or weaker metal, namely, the *iron*, has actually been approved of and pronounced *extremely simple*, in the following words:—"Altogether, this is the simplest and apparently the most efficient form of sheathing for iron ships that we have seen"!

It has been well and truly remarked that "It should be the function of engineering papers to explode all palpable bubbles, and to guide public opinion aright in matters beyond popular analysis and appreciation;" otherwise "will the public lose confidence in those blind guides by whom they have been so much misled."

The "Caledonia," iron-cased ship, has been sheathed with teak three inches thick, and this covered with a new description of metal sheathing, being copper on one side and pewter on the other, the idea being that no galvanic action prejudicial to the iron can be excited by this arrangement.

The "Zealous" has been sheathed with teak planks three inches thick above the water-line and four inches thick below it. In carrying out this plan it has been determined in future to bolt the planking directly on the plates, to avoid weakening the planks by the grooves they formerly cut in them.

Ever since the fouling and corrosion of the hulls of iron ships showed the necessity of preventing them by sheathing, it has been a desideratum to obtain a simple, practical, and efficient mode of attaching the plates of metal or sheathing to the iron hulls; and though many plans have been patented and proposed, all more or less ingenious or objectionable, none can at present be said to be in use or capable of fulfilling the requirements of the case in a satisfactory or efficient manner.

In 1862 Mr. Mallet, who is considered by some people as no mean authority on such matters, said that "any attempts at coating an iron ship *directly* with *any* metal sheathing is *quite out of the question; the mechanical difficulties are insuperable.* You cannot attach sheathing firmly to the skin of an iron ship in any way, but you injure the strength and diminish the safety of the ship enormously. If it were possible to get the hull of an iron ship into a condition that it would not corrode at all, there would no longer be any difficulty about preventing it from fouling at all."

It may be that, on examining Mr. Daft's plan of constructing iron ships and vessels and sheathing the same, Mr. Mallet will be disposed to alter his extremely decided opinion, and, as a mechanic, recognise the truth of the saying that "there is no finality in engineering," before he again ventures to pronounce so decided and dogmatic an opinion on a matter which in *a twelvemonth* afterwards is *fully* and *completely solved* in the two points, one of which was "*quite out of the question,*" and the "*mechanical difficulties*" of the other were "*insuperable.*"

Numerous attempts have been made to attach the metal used in sheathing to the bottoms of iron ships, and "sticking" them on by means of some adhesive material has been a tolerable favorite; next has been that of drilling through the hull or skin of the ship a quantity of holes, through which the bolts holding on the wood sheathing passed, on which wood the sheathing metal was nailed; next, ribs or ridges of iron were attached to the hull, vertically or horizontally, and the wood sheathing wedged or jammed in between them, and the metal sheets put on this; in fact, several modes have been proposed or patented for this purpose, but, so far as experience shows, have met with but a very limited amount of patronage. All the plans for building a wooden ship on an iron hull, and then coppering, yellow-metaling, or sheathing it, are but very unsatisfactory and objectionable plans, increasing the midship section of the ship without adding to the strength of the vessel, and bringing a metal of a superior galvanic power into close connection, by means of damp wood and water, with a weaker one.

We often hear it dogmatically asserted that zinc is of no use for sheathing *iron* vessels, because where it has been used on *wooden* ones it soon fails, and this from the formation of an oxide or carbonate which is so hard as to turn it into a *permanent surface.* That this is true there is not the slightest doubt, and the author has seen wooden ships sheathed with zinc in a most surprisingly foul state. A little consideration of the subject, however, would have shown that this failing arises from the lack of the very circumstances required to prevent it, viz. exfoliation, which, it may be observed, is most readily and surely obtained, and to any required amount, when the zinc is placed on the hull of an iron ship.

Prior to 1833 the copper used on the bottoms of the ships of the Royal Navy did not waste at a greater rate than one ounce per square foot per annum, whilst subsequent to this the average loss per sheet was four ounces per square foot per annum. There can be little reason to doubt that this was owing to the employment of iron fastenings, and that galvanic action took place between the iron bolts and the copper sheathing, thus preventing the exfoliation of the copper and destroying the iron, causing the ship to become "nail-sick."

When, however, copper and yellow-metal fastenings were introduced and iron given up, the action of the sea-water on the copper sheathing had uninterrupted sway, and the copper exfoliated at the increased rate mentioned, causing great excitement amongst the Government authorities at this increased waste, and no small amount of inquiries and investigations were made to find out the "reason why;" but it was finally concluded that it was the fault of the copper, which proved itself not to be so good as that formerly used!

Mr. Scott Russell remarked at the Institution of Naval Architects, in 1866, "The great merit of copper is that it decays. You all know how rapidly it wears out. And what do we pay the price for it for? We pay the price of copper in order that by its rapid decay, and its passing off and taking the barnacles with it, we may keep our ships pure and clean."

The general idea in regard to the sheathing of ships seems to have been that *it ought not to waste away,* and that any tendency to this was an evil that ought to be checked. This wish to "eat the cake and have it too" is very bad policy, and shows a complete ignorance of the mode in which the sheathing acts; for the fact has been patent to any one that took the least trouble to know the "reason why," that the sheathing *must* "perish," in order to "keep clean;" and that if it does not perish the sheathing is preserved, but at the expense of a constantly dirty bottom to the ship.

It is now known to all who have studied the subject that the cause of copper, yellow metal, zinc, and other metallic alloys placed on a ship's bottom, keeping clean and free from fouling, is the exfoliation of the metal and the constant renewal of the surface caused thereby, through which the adherent matter is, as it were, sent adrift, by the friction of the water against the metal sheathing washing off the exfoliated parts or films. From this it will be evident that there is just such a rate of exfoliation as will secure this great and important advantage without causing too rapid and unnecessary a destruction of the metal, which it is most important should be made to last as long as possible, provided it does not introduce any other disadvantage, or interfere with the proper carrying out of the end for which it is applied.

A vessel with an iron hull, cased with wood and sheathed with copper or yellow metal, is in a state of perpetual risk and danger, as a blow, grounding, galvanic contact of the two metals, or the detachment of the sheathing, must render her docking an immediate necessity, unless it be preferred to run the risk of allowing galvanic action and corrosion to take place. In fact, a ship so circumstanced can only be looked on as a huge galvanic battery, always ready to do mischief, and rapidly destroy the positive or weaker metal, viz. the iron of the hull of the ship, when sufficient metallic contact shall be produced, and always in operation through the contact afforded by the water or dampness in a less rapid degree.

Rear-Admiral Sir F. E. Nicholson, C.B., remarked, at the Royal United Service Institution, on the 20th March, 1865, that in the "Caledonia" "a belt of wood was originally placed between the Muntz's metal on her bottom and her iron plates. It was well known that damp wood is a partial conductor; still it was supposed that this would be a better plan than bringing the Muntz's metal right under and in contact with the armour plates. If that had been done there is no doubt that the armour plates would have been ruined."

# CHAPTER V.

## FOULING.

Fouling, or the adherence of barnacles, seaweed, zoophytes, and other matters, to the bottom or immersed portion of a ship's hull, constitutes a most expensive and objectionable feature in iron ships, and one which has employed an enormous amount of time, ingenuity, and money, in essaying its removal. The enormous number of patents which have been taken (some 300 or more in number), and the numberless experiments which have been made to prevent fouling and corrosion in the hulls of iron ships, must be taken as proofs both of its extremely difficult solution and the great desirability of its being achieved.

By fouling, the speed of a ship is diminished, and delay on the voyage encountered, whilst, if it be a steamship, there is the increased consumption of coal, with a less distance done per ton, increased wear and tear of boilers and machinery, and the increased risk of delay from breaking down; and this involves the necessity of going into port, docking, cleaning, painting, or coating, and the great expense and loss of time incurred in carrying out these requirements, whilst if it be a ship of war, to all these drawbacks must be added that of having to return from a distant station, the loss of its services whilst away, and the delay caused in getting back to the station again, with the expenses in so doing.

In order to prevent a ship proving a loss to an owner, "it should be kept moving," or, in other words, "earning money;" and so long as this can be done many will put off the docking and cleaning until they are literally obliged to do it, or there are some repairs of hull or overhaul of rigging which would enable one operation to serve for both.

The cost and loss of time involved in cleaning an iron ship and keeping her in proper order are very great; and though some vessels may be kept afloat and at work when they are in such a state as ought to ensure their cleaning and overhaul, still this does not prove that the cleaning is unnecessary or should not be done; and it is well known that many will prefer a loss of speed to frequent docking and cleaning, even although they may admit that such cleaning ought to be done.

As the value of a ship must in a great measure depend on her speed, that is, on the quickness of her getting goods to market and the number of voyages she makes in a given time, it is imperative that she should not be delayed on her course by shell-fish and seaweed attaching themselves to her, nor by being kept in dock for their removal. It is often found that a ship loses 25 per cent. of her proper speed by this cause, besides a considerable time by going into dock, when foul, to be made clean again.

Iron ships are generally built with lines to obtain speed, but the very material used, and the mode in which it is employed, are found to be the most certain means of losing it. Iron, without *some* mode of preventing it, fouls rapidly, and this fouling decreases the speed in proportion to its amount, whilst at the same time the expenditure is increased without one corresponding or proportionate benefit being obtained.

The numberless patents for preventing fouling and corrosion of iron ships show how generally these evils are admitted, and the necessity felt to exist for removing or mitigating them; but on examination it will be found, as a rule, that but little knowledge of the conditions involved, or the best mode of most practically fulfilling them, have been exhibited in these attempts.

In spite of the numerous and continued examples of the great expense, loss of time, loss of speed, and other serious and fatal drawbacks caused by fouling, there are still people to be found who attach no importance to it, and maintain that it is only in peculiar instances that it has produced any annoyance.

Mr. Lamport, at the Institution of Naval Architects, in 1864, observed—" Some gentlemen made light of the question of fouling. I took up the ' Shipping Gazette ' the other day, and looked at all the ships overdue from China, the longest average voyage we have. They were all of them over six months on a voyage, which is from two to three months more than they ought to be. Out of seven so overdue six are iron. Will any gentleman tell me that an iron ship can be cheap, can be profitable, if she runs the risk of being from two to three months overdue?"

Mr. Grantham, C.E., said, in 1861, at the Institution of Naval Architects, speaking of iron ships—" Many attempts have been made to keep these ships clean in tropical climates, and it is most essential that those which have to go upon foreign stations for a period of three or four years at a time should be kept clean. A ship, with all our present knowledge, sent on such an expedition, in twelve months will be almost useless. I have heard of one instance in which the screw port was so choked with barnacles that they could hardly get the screw to start."

Fouling involves an enormous loss of money and time, and the following heads will be found to comprise the chief divisions:— 1. Docking and undocking. 2. Labour of cleaning bottom and putting on coating. 3. Cost of coating materials. 4. Wear and tear of ship's bottom when scraped or cleaned in being prepared for coating, including the injury done to the rivet-heads by scraping. 5. Attendance of officers at docking and undocking. 6. Steam-vessels at ditto. 7. Unloading and loading stores. 8. Stowing and unstowing stores. 9. Wages of unemployed crew. 10. Loss by reduced rate of speed. 11. Loss of service of ship, officers, and crew, while in dock having the bottom scraped, &c., &c. fourteen days each six months.

It is said that the Peninsular and Oriental Steamship Company expend some £70,000 a year in keeping the bottoms of their vessels clean and free from fouling, all of which would be saved were this serious drawback of fouling overcome.

If the amount of money actually expended and loss of time incurred in keeping clean the bottoms of our iron ships, either in the Royal or the Merchant service, could be obtained at the close of each year, and put on record, there can be no question but that the result would be beyond conception, and could not fail to cause far more attention to be given to its prevention than has apparently hitherto been the case.

So far people seem to have come to the conclusion that fouling cannot be prevented, and is an evil inseparable from the use of iron; but that it is so, or ought to be so, is quite another question, and there can be no doubt but that the constant failures of the innumerable nostrums so frequently brought forward as perfection have in no small degree contributed to perpetuate this state of things, and disposed people to fancy that prevention in a perfect manner is quite unattainable, and that nothing further need be desired.

It is stated that the "Solferino," "Provence," "Normandie," "Invincible," "Gloire," and "Couronne," six of the iron-plated fleet belonging to the French Imperial Navy, have had to pass 331 days in dock since the 1st day of January, 1865, up to the 8th of March, 1866, which gives an average of fifty-five days each during a period of little more than fourteen months!

Mr. Lamport asked, at the Institution of Naval Architects, in 1864—"I put it to any owner of an iron ship whether he would not willingly pay the cost of coppering to avoid the drawbacks of fouling?"

Mr. Grantham said, at the Institution of Naval Architects, 1865—"The one and the only difficulty which stares us in the face, and I have spoken about it so often that I do not like to say much about it now, is the impossibility at present of keeping our iron ships clean at the bottom. I believe I may say with safety that every possible objection has been long ago overcome, except that one difficulty of fouling."

Mr. Mallet remarked, at the Royal United Service Institution, in 1862—"The importance of the subject I think it would be difficult to overrate; for highly important as the corrosion and fouling of iron ships has been at all times to the mercantile marine in a money sense, it becomes of far more vital importance now that iron ships are certain to be applied for war purposes; for if it be a fact that a war ship sent to sea, after some six or eight weeks loses a mile an hour of her speed from alteration of the surface of her immense hull, or, as we may call it, from fouling—if a vessel so circumstanced be caught by a clean ship of the enemy that has got the mile an hour still, the former is taken at a disadvantage which *nothing can make up for,* and so the mere state of her surface determines whether she can keep the seas or not. *Hence this question of fouling has become a national one.*"

Captain Selwyn says—"Speed is universally acknowledged to be one of the first desiderata for every man-of-war, and that it is an absolute necessity for the weaker ones. It is no less true that if we are to avail ourselves of the thinner and lighter material—steel—in the construction of ships, special care must be taken that no injurious galvanic action which can be avoided operates to reduce its original strength."

Lord Clarence Paget, in commenting on the serious drawbacks caused by the fouling of our iron-clads, and the foul state they were constantly in, spoke of the importance of some means being obtained by which it would be prevented, and described these vessels to be "always as foul as lawyer's wigs!"

The rapidity with which fouling takes place in the spring and summer seasons can hardly be conceived by those unacquainted with the subject; and where the circumstances and conditions are favorable to its progress, it becomes a serious and annoying, if not dangerous, evil, and one which requires the most unremitting care and attention to prevent the occurrence of serious results.

It is related by some of the Southampton pilots that they have found it necessary during the spring and summer seasons to lay their vessels on shore at least once in every fortnight, to scrub off the weeds and slub which form on their bottoms.

Some of the St. Mawes' pilots, near Falmouth, have stated that they have invariably been obliged to clean the bottoms of their vessels once every fortnight, and if left for a month great difficulty has been found in removing it, the accumulation having become so thick and so strongly adhesive.

The "Monarch" steamship, belonging to the Electric and International Steamship Company, required docking every six months, and was found each time to be completely covered with vegetation, barnacles, shell-fish, &c.

One captain of an iron ship says—"When I left London the bottom was coated with red lead and tallow, and upon my arrival at Shanghai, after a long voyage of 150 days, the bottom was so foul that I was compelled to have the ship docked. I am convinced common paint and tallow are useless, either for preserving the ship from rust or in keeping clean."

The Peninsular and Oriental steamer "Northam" got so foul on the voyage from Sydney to Point de Galle that her speed fell off considerably, although coated in dock previous to leaving Sydney; and having no time to dock again at Ceylon, the evil increased so fearfully on the return voyage that several days were lost by the reduction of speed.

One of the commanders of the Peninsular and Oriental Company writes—"I have been in the habit of taking out several iron steamers before to distant parts of the world, coated with different compositions, but *invariably* found that their bottoms were fouled with weeds and barnacles before we had been *six weeks* at sea, much retarding the latter part of the voyage, notwithstanding we had taken opportunities of scrubbing them off as far down as we could reach."

The General Screw Steam Shipping Company required to dock their Cape steamers every voyage to clean and re-coat.

Admiral Sir E. Belcher, C.B., has stated that a copper-bottom frigate, after lying four or five months in the Medway, will in this short period accumulate from four to five tons of mussels, &c., on her sheathing.

It is said that when the "Royal Oak," an old sailing man-of-war, was broken up at Bermuda some few years since, the layers of oysters, one over the other, were so thick that the weight was estimated at upwards of *eighty tons!*

The iron troop ship "Adventure," when examined, after nine months' absence from England, was found to be encased with oysters and very foul, in spite of a smearing and plastering before her departure.

The 'Times' of the 1st August, 1864, relates that "The "Dromedary" iron steamship, in Her Majesty's service, is just undocked at Woolwich, having returned from the Mediterranean, with an incredible amount of seaweed and barnacles attached to her, which have adhered in spite of all the inventions tried and said to prevent them."

The 'Times' of the 23rd of September, 1864, stated that, "Owing to the length of time the "Achilles" has been lying in the river, her bottom has become exceedingly foul, and the examination of her hull by one of the professional divers has resulted in the discovery that the whole of her bottom is completely covered with marine insects, barnacles, and seaweed, some of the last being as much as two feet in length. The bottom of the "Achilles," it may be remembered, was coated over with Hay's anti-fouling composition before the frigate was undocked, and, as she has been lying some nine months in Chatham Harbour, a pretty correct estimate may be formed of the state our iron-clads will be in if detained only for a very short time in tropical waters. In the case of the "Achilles" fully two knots an hour may be deducted from her speed if sent to sea in her present condition."

Captain Fishbourne stated that when he was on the coast of Africa an iron whaler came out from England; and though she had only left *six months,* and been cleaned as well as they could at sea with long brooms and ropes under her bottom *every month,* she had long grass and barnacles of immense size attached to her, in consequence of which she was not safe, as she would neither sail nor steer, and *was not manageable.*

When the "John Garrow" iron sailing ship returned from a voyage to Bombay, on which she was absent twelve months, she was found exceedingly foul and covered with a dense mass of barnacles; in consequence, she made a very tedious voyage.

The "Triton" iron steamship was found, when docked at Keyham, to be nearly covered with oysters of an enormous size, the interstices being filled up with zoophytes and large acorn barnacles as big as egg-cups, one overlapping the other.

The 'Times' of November 18th, 1864, relates that though the "Achilles" iron frigate "was covered over before her launch with the anti-fouling composition of Mr. Hay, the Admiralty chemist, so foul had the bottom of that vessel become while lying in Chatham Harbour preparing for sea, that in the run made from Chatham to Devonport her speed fell off more than three knots per hour from her steaming rate on the occasion of her official trial at the Maplin Sands. When docked at Devonport the bottom was not only foul, but many of the plates were left completely bare of composition, and white corrosion had in many instances eaten away the plating to a depth of one sixteenth to one tenth of an inch."

The 'Times' of the 25th January, 1865, reported that "The "Royal Oak's" bottom was found to be foul beyond all conception. Immense quantities of zoophytes, weed, and coralline flourished in the wildest profusion, and so hard had the little insects formed their habitations that nothing short of a general scraping with short scrapers would remove the incrustations, the result of barely six months' accumulation. Whether this rapid growth is due to the Muntz's metal with which the ship's bottom is sheathed, or the result of some general galvanic action, is hard to conjecture; but what another grand field for the experimentalists!"

In the 'Times' of 21st June, 1865, is the following extract from the letter of their Malta correspondent:—" The " Resistance," 16, iron-clad, is still in dock, having her bottom cleaned and coated. On being left dry it is said that no less than twelve inches of grass were found attached in some parts, although she had been hogged within a month."

In the 'Times' of 3rd November, 1865, and the 'Mechanics' Magazine' of 10th of November, 1865, is the following account of the state of the "Agincourt":—"The condition of the "Agincourt," 26, at Devonport, has created considerable surprise in the minds of the officers of the dockyard and others. About six weeks since she was removed from the Prince's Dock, after having been coated a second time with Hay's anti-fouling composition, and was placed alongside the shear-hulk in Hamoaze, where she received her five iron masts and was otherwise prepared for preliminary trial of her engines, which took place on the 12th ult. On Monday last the "Agincourt" was replaced in Prince's Dock, and as the water was pumped out her bottom below the line of flotation looked, as one of the artisans described it, 'like a field of grass,' so regular was the growth of the weeds. Some were nearly two inches long, and it extended from stem to stern and down to the keel. It is supposed that if no composition had been applied, vegetation could not have advanced to the same extent."

The French iron-cased frigate "Invincible" had not been docked for ten months, and when taken in her bottom was in a most surprisingly dirty state. The copper was covered with a thick mass of marine vegetation, a sort of white coral, and many kinds of shellfish formed a stratum which completely hid the sheathing, and was five centimètres or nearly two inches thick over certain parts. There were also in certain places patches of oysters, which firmly adhered to the sheathing. There were not less than *ten tons* of vegetable matter or fouling removed from the bottom.

When this vessel was tried after her completion in 1862 she attained 13·5 knots under full steam, with 53 to 54 revolutions of the engines. In April, ten months after she was undocked, she was tried under full steam, the weather being calm and the water smooth, when her greatest speed was 9·8 knots with the engines making 51·5 revolutions. After having had her bottom cleaned she was again tried, when her speed was found to be 13·2 knots with the engines making 53 revolutions.

The "Taureau," another French iron-clad, was found to have fouled in a very short time, for, having been undocked on the 17th November, 1865, and examined on March 15th, 1866 (four months), a quantity of heath-like vegetation was found along the water-line and below it, which was found to be swarming with young mussels, and under the bottom was found a great quantity of little shells about the size of a pin's head, and there was also a great quantity of slime of a green colour, and tolerably thick.

One iron ship of nearly 800 tons register, which had been eight months in a warm latitude, had thirty *cartloads* of barnacles (an estimated weight of twenty-eight *tons*) removed from her bottom, an encumbrance which could by no means have improved her speed or sea-going qualities.

The Inspector of machinery to the East India Company at Bombay has stated that when the "Indus" steamer was taken into dock at that port he took barnacles off the bottom *twelve inches thick* and *eighteen inches long;* and he also mentioned that the "Nemesis" was a mass of barnacles upon the bottom.

The superintendent of the Peninsular and Oriental Company at the same place says—"Between Bombay and China no ship should be longer than *four months* without examination. The fouling commences immediately after undocking. To maintain the regularity of a mail service, four months is the *outside limit* that an iron ship should run without cleaning and painting on the Bombay and China line. The "Pottinger" iron steamer, which left England in February, 1847, to perform a voyage to India round the Cape, was docked at Bombay in September. The bottom was very foul; the barnacles were six inches long, in large clusters. In the run a second layer had begun to form. The "Pekin," which left England in February, 1847, was docked at Bombay in October. I can compare her to nothing else than a half tide rock. The barnacles were nine inches long, the second strata being complete, with a feathering coral formation sprouting from cluster to cluster. The stench from the animal matter was so great that no one could remain on board at night, and the paint was tarnished. The "Pekin," although a fast-sailing ship, had her speed reduced by the fouling to *six and a half knots per hour!*"

The "Oberon," whilst on the Brazilian station, was coated with a mixture of lime and mineral tar, which fouled so badly that in three months it had to be scraped off.

In November, 1863, the "Recruit," iron-paddle despatch boat, had the hull coated with the patent anti-fouling compo's of Messrs. Hay, Wilson, and Crispin, each claiming to possess *the* secret; and when taken into dock in August, 1864, the following proved to be the result:—Hay and Crispin's portions, each very foul, a large number of mussels closely adhering to the iron work, and a *considerable amount of corrosion.* Wilson's compo' was not so foul, but there was *more corrosion than with the others.*

The 'Times' remarked, that "both compositions (as, indeed, has been the case more or less with every invention of the kind hitherto brought under the notice of the Admiralty) have turned out to be *complete failures*, as, on the water being pumped out of the dock in which the "Recruit" had been placed, every square inch of the surface of her hull below the water-line was found thickly coated with weeds, sea-grass, barnacles, and various kinds of animalculæ."

In 1865 this same vessel, after having been coated with Hay on one side and Crispin on the other, was found on examination to have Crispin's covered completely with grass, and Hay's with all kinds of fish, crabs, &c.

In 1863 the "Recruit" iron paddle-wheel despatch boat had the starboard side coated with Mr. Crispin's anti-fouling composition, and the port side was coated with that of Mr. Hay, the Admiralty chemist. The result, as reported in the 'Times' of October 17th, 1863, was as follows:—"On the starboard side the entire surface was covered with grass about a foot in length, with which were mixed thousands of sea-worms and barnacles. A minute examination led to the discovery that every portion of the composition had been eaten away from the iron plates, leaving nothing but the coating of red lead applied by the dockyard workmen. On the port side Mr. Hay's composition was found to be still adhering to the iron plates, which were coated over the length of the vessel with a kind of fibrous seaweed from one to three inches in length, and swarming with small shell-fish. In some parts of this portion of the vessel's bottom the weeds were larger and more matted than on the starboard side, while the barnacles here were also very large, the composition being completely penetrated and the iron plating exposed. Altogether, the bottom of the "Recruit," which had been only *twelve weeks* out of dock, was more thickly covered with marine formations than many iron vessels which had been twelve months afloat."

In February, 1865, Her Majesty's Ship "Valiant" was docked at Portsmouth, and one side was coated with a "poisoning" anti-fouling compo', of which mercury was the basis, and it was asserted by the inventor that it "not only effectually prevents the least accumulation of animal or vegetable matter, but at the same time preserves the iron from oxidation;" and the other side had applied to it one of the preparations of copper. In *five months* after, *both sides* were found thickly covered with barnacles, weeds, &c.

At the same time orders were given by the Admiralty for the application of no less than *seven* coats of Green's "anti-fouling" compo' to the bottom of Her Majesty's Ship "Achilles," the cost being nearly £1000. In *three months* after, the ship was docked, and on examination it was found that this expensive operation had been a *complete failure*, and the mercurial preparation or compo' was nearly as bad. Both these were scraped off, and *another* "improved" compo', containing copper, was applied to both sides.

On the 6th April, 1865, the 'Times' announced that the

"Orontes" troop-ship, and the "Hector" screw iron frigate, had both been docked at Portsmouth, to examine, report upon, and replenish the "preservative" and "anti-fouling" compositions with which the immersed portions of their hulls had been coated when they were last in dock. The "Orontes" was found to have the bottom free from any important accumulation of weeds, but "under the counter of her stern, and in the run of her lines to her screw aperture, she was thickly encrusted with barnacles, and the bottom was dotted all over with patches of rust, the *rivet-heads* in many places showing evident signs of being *affected by the copper* contained in the "anti-fouling composition." Then follow the remarks that, "as a 'preservative' to the ship's bottom, the composition appears to have *utterly failed.* As an 'anti-fouling' preparation the result is rather more favorable; but this slight advantage appears to have been *more than counterbalanced* by the *failure in 'protective' qualities* to the iron of the ship's bottom. The "Hector," on being examined in dock, was found to be covered with long weeds hanging in tufts and festoons, with a moderate quantity of barnacles and a large deposit of corallines aft."

The 'Times' of November 17th, 1863, reported that the "Warrior," having been taken into dock *four months and a half* after a former docking, when she was coated below the water-line with a "preservative" and "anti-fouling" composition, and had at the same time three patches of "vitreous sheathing" attached to her port side, it was found on examination that "the ship's bottom, as she now lies in dock, has the appearance of a well-made thrummed mat, being covered with a fine crop of tuft weed, which must have grown at the rate of about three quarters of an inch per month since the ship has been afloat to reach its present condition. There are existing indications of *mischief to the rivet-heads* at the bows of this ship to warrant a careful scraping and examination of *every part* of the ship's bottom from keel to water-line."

The 'Shipping and Mercantile Gazette' of September 1st, 1865, records the fact that the "Ceylon" and "Poonah," iron steamships of the Peninsular and Oriental Company, were each coated with a "new" compo', and the result was "most extraordinary." Both ships have returned after their first voyage of a few weeks in a most shocking plight. The "Ceylon," notwithstanding she had been twice scrubbed abroad in *less than two months,* was found covered with grass from twelve to eighteen inches long, and barnacles and zoophytes, &c., had began to form all over the bottom, so that she was delayed on her homeward voyage several days beyond her usual time of arrival. The "Poonah" was nearly as bad after only six weeks' absence."

A great idea seems to have taken hold of some of the inventors of anti-fouling compositions, which is that the mucus of fishes was the pattern to be kept in view in any attempt to keep iron ships' bottoms free from fouling, and one inventor has stated "that the most valuable and persistent protection for the bottoms of these vessels will be found in the direction of mucus, and not in that of metallic paints." One person has actually proposed to adopt some means to cause a constant film of oil to be kept on the surface of the hull of a ship, so managed as to be perpetually renewed as it comes off, and thus keep the bottom clean.

Attempts have been made by some inventors of compositions to obtain one which shall act by a constant renewal of the surface, and in this some have succeeded so far as to keep tolerably clean for six or eight months; but this is very far from what is required. What it is of the utmost importance to obtain, is something which shall keep clean for *not less than three years*, or the period for which our men-of-war are commissioned; and this experience has so far shown has not, and cannot be obtained by any composition.

When anything is used which does not do this for the period named, it must be looked on as a failure, for the most important point to be attained in our large iron-clads is *that they should not have to be docked during their commission; and any plan which does not secure this must be deemed useless.* No composition will adhere equally throughout, from the wet or damp state of the plates, the weather, &c., either in being laid on or when laid on; and as this difficulty cannot be overcome, it is one of the weak points inherent to compositions. One thing is certain, that however well these may answer when *experimented* with, they *fail when applied in practice.*

It is said that our iron-clad ships have to spend fourteen days in dock every six months to have their bottoms cleaned, if, therefore, this be correct, and everything seems to prove its truth, each ship would average one twelfth of her time whilst in commission in being docked solely to have the fouling removed! and this, too, in spite of the great variety of "successful" (?) "anti-fouling" compositions which are said to be either in use or else being tested, and of which we so frequently have such flattering reports.

These compositions, as a rule, would seem to have been originated for the purpose of cultivating and improving marine productions, as they are evidently based on agricultural experience; for first we have the red lead or the preservative, then the "anti-fouling composition" or the manure, then comes the "top dressing," after which is the harvest, generally resulting in a heavy crop of mixed productions, as objectionable and useless as they are various, and as expensive and troublesome to reap as they are annoying and prejudicial when collected.

The variety also in the composition of these "manures" is as great as amongst those used by agriculturists, who we hear talk of guano, phosphate, superphosphate, ammonia, &c., and we find that even guano itself has been proposed to be employed by some of the promoters of the new system of marine agriculture!

Experience shows that they do not last, and it is found necessary to have a "bottom cleaning" and "plastering" or "smearing" after each long voyage, besides frequent "hogging;" in fact, it is admitted that the *best* of this army of "anti-fouling," "anti-corrosive" preparations do not keep a vessel clean for a voyage to India and back, even under the circumstances of the ship being able to leave on her return voyage without having to remain in harbour any time longer than needed to discharge and load; and their repeated and continued failures, in spite of the highest pretensions to perfection, have caused it to be remarked that "a comparison of the results of the great number of expensive compounds now being applied to the bottoms of Her Majesty's ships under the name of 'anti-fouling' mixtures or compositions, would almost lead to the belief that they tended to *encourage* rather than *discourage* the growth of marine animalculæ or weeds, even in English waters."

As regards the use of plaster as an anti-fouling, anti-corrosive material, Mr. Lamport well observed at the Institution of Naval Architects in 1864—"The structure of an iron ship, from her length and material, must be flexible. Her own weight in a graving dock, independently of the action of the undulations of the waves and of blows from heavy seas, to say nothing of the strains from varying draughts of water and differently disposed cargoes, from touching the ground, or from collisions, will cause sufficient vibration, if not actual working, to loosen, perhaps break up, a brittle coating of cement. *If once the adhesion be lost, and moisture impregnated with chemical vitality ooze through a crack in the cement, the remedy will increase the disease by retaining and hiding the mischief of the obnoxious influence.*"

According to the experience of Admiral Sir E. Belcher, C.B., corallines were more difficult to be removed from vitreous surfaces, and could not be removed by an ordinary scraper; but wherever they came into contact with copper which is slightly oxidised, they scaled off immediately, because they *came off with the oxidised portion.*

In 1862 the "Sharpshooter" iron steamship is related to have became so foul with oysters, that when docked at Portsmouth they had to be "dubbed off" with adzes, and came off in flakes of shell of eighteen inches to two feet square, in all cases *bringing off a considerable amount of scale from the iron.*

An officer of many years' standing in Her Majesty's service, and who has had very considerable experience in regard to fouling, &c., writes thus respecting the adhesion of barnacles, &c., to ships' bottoms, and the trouble in detaching them:—"Whilst on the coast of Africa, slave catching, in 1850–51, in H. M. S. "Phœnix," we used frequently to hog her bottom, which would become foul in a very short time, and occasionally it was necessary to remove as far as we could the barnacles on the screw (which screw we had not the power of raising), and for this purpose a Krooman went down with an old chisel and scraper. The barnacles stick more firmly than a limpet to a rock."

It is stated in the 'Transactions of the Institution of Naval Architects' for 1866, that the "Industry" was coated with an "anti-corrosive, anti-fouling cement," invented by Mr. Szerelmey, with the following results:—"The 'Industry' was undocked at Woolwich on the 5th August, 1858, with Mr. Szerelmey's composition on her starboard side, whilst the port side was payed with 'Peacock's composition' upon red lead. The vessel was docked again on the 28th May, 1859 (in less than ten months). Upon examination it was found that *corrosion existed on both sides* in patches, *the starboard side the worst,* and both sides *foul* with weeds and barnacles."

Captain Stewart stated that "There is an iron fire-float on the River Medway at Chatham which has had several compositions tried on her bottom. There are also some buoys moored in the Medway on which compositions have been tried, including Portland cement, and *I am a witness to the failure of the whole of them.*"

Admiral E. P. Halsted, whose indefatigable endeavours in aid of progress, and conscientious, careful, and thorough investigation of any subject he takes in hand, are well known, in his interesting and valuable lectures on "Iron-cased Ships," read before the Royal United Service Institution in 1861, speaks of the "great and rapid fouling of the ships' bottoms, due to the facility for adhesion offered to every marine substance by the surface of every material yet applied for the protection of the bottom from corrosion, and this objection, *costing its annual tens of thousands among all concerned,* remains to the present day. If the speed of the "Warrior" should be reduced from fourteen to twelve knots, which a reference to the cases of the "Himalaya" and other transports of iron will show to be no excessive loss from the rapid and great fouling of the bottoms, then such reduction will, in accordance with well-known laws, be equivalent to a loss of about one third or 400 nominal horse-power in the efficiency of her engines; and for this loss there will be no compensation in any corresponding reduction of the fuel used, for the whole steam stable will have to do its utmost to obtain even this lower speed, and will demand its food accordingly. Therefore, as compared with efficient work, this lower speed must be obtained at a loss of about £40 a day. Present experience tells us that this loss must be incurred throughout such period as the obstruction may be allowed to last twice a year; and, according to present knowledge, the sole remedy against both its duration and increase is in a process of docking, cleaning, drying, painting, varnishing, &c.; and who is to say how long one of our 6000 ton ships, with a draft of twenty-eight feet, will not have to 'stand knocking' at dock gates, which they cannot enter until tides permit this remedy to be applied, whilst they must be equally forbid to go to work at sea again until it is applied, under pain of the horses eating their very heads off without avail. The number by which we may prepare to multiply this annual loss in money, time, efficiency, and labour, but, above all, in absence from stations when possibly most wanted, amount to seven, to be multiplied again in each case by two, so that there is likely to be a very pretty little bill to pay each year for the continued liability of iron bottoms to foul, even if our iron-cased ships should be limited to the number at present built or building. But as I gather that my countrymen intend not to give over our great rival 'permanently' that commercial superiority she has contrived so astutely to seize from us at present, the above multiplier is likely before long to be largely augmented, and thus the matter, in whatever light viewed, assumes the proportions of a national question; and it is alone by regarding it in this important view that it is at all likely, in my opinion, to be successfully solved, for in respect to commercial shipping it has been felt as a weighty question long enough to have been solved many times over before now, if its solution had not been in reality a very stiff job."

So thoroughly impressed was the admiral with the desirability of having this serious drawback of iron ships obviated, that he continues—"The question here mooted is one of national interest far above the money cost involved in its solution; and if only in the bare hope of drawing national attention to it, so as to elicit an expression of public opinion whether a more public mode of solving it may not this time be adopted. I beg to set the ball a going thus:

"1. May the Legislature be induced to vote at once the sum of say £10,000, for the discovery of the more effective means of keeping clean the bottoms of ships of iron, to the same extent as copper now keeps clean the ships of wood, competent judges being publicly appointed, the scale and conditions of awards being published, and the whole available talent of the country invited to compete.

"2. Let every facility of all public establishments and all official and relevant information be fully accorded to all competitors whom the judges may acknowledge to be such, all necessary precautions being taken to distinguish between true men and mere pretenders.

"3. No competitor securing an award to be allowed to patent the discovery awarded.

"Should a twelvemonth of such effort fail to elicit what is required, even the test afforded by such an effort would be most valuable in its proof that to invest iron itself with the desired property must be left for mere time or for some happy accident to determine; but in order that the effort be not barren, let the terms of competition equally apply to the substituting for iron of any other metal, simple or compound, but equally as strong and otherwise unobjectionable."

Admiral Halsted remarked at the Institution of Naval Architects, in 1861—"Now I come to another terrible business, and one in which, I hope, my colleagues in this institution will take an active part. Here is the "Warrior," with her 1250 nominal horse-power engines, to go 14 knots an hour. But, pray, for how long? How many weeks will elapse at sea before the fouling of her bottom will reduce her 14 knots an hour to 12, or even less than that? As everybody here knows, perhaps, better than myself, the fouling of the bottom of iron ships is a question connected, and closely connected, with the nature of the material itself; but I think it is not generally understood that it is not a mere question of the difficulty of preventing the corrosion of the bottom of iron ships. There are a dozen ways by which actual corrosion of the metal may be prevented, but the misfortune is that all these appliances have the effect of presenting such an enticing surface to marine substances and animals, that they carry on their little operations till there is no end of them, and in six months the surface of the bottom of your ship is destroyed, in a great measure, for all purposes of speed. It is wonderful the money paid away in this country on that account. We possess some 600 iron screw ships, and there is not one of them but is subjected to this difficulty at least twice a year. And it is not the mere expense of hauling into dock, cleaning the bottom, and repainting; but it is the number of steam horses that have to feed to their fullest extent constantly, although the effect produced by their efforts is gradually diminishing. Neither is it that the steam horses cannot take the amount of food; on the contrary, the tendency is rather to over-feed them at such times, so that the reduced speed has no compensating economy; but the whole effect is a dead loss. What, then, should prevent the council of such an Institution as this submitting that some definite means should be taken to overcome this disreputable fact, which has exposed us to so much public loss up to the present day. I attribute our neglect of this point entirely to the fact of the Government condemnation of iron ships hitherto as unfit for the purpose of war. Had it not been for that most unjust and impolitic condemnation, I believe a remedy or a substitute would, as a great national object, have been provided long ago."

Hitherto attention has been almost exclusively directed to obtaining some paint, varnish, composition, plaster, or other contrivance, which, when applied to the coating of vessels' bottoms, shall prevent the destructive agency of the worm, if of wood, and the waste or wear of the copper sheathing; and when applied to iron vessels, the fouling and corrosion of the plates; but so far it must be said without success, for although some of them may do so tolerably well for six or eight months at a time, still this is far from what ought to be obtained or should be desired. The great aim of all who try in this direction should be to obtain a plan which shall be perfectly successful in both directions for the whole period of a ship's commission—say three to five years—and so do away with the frequent dockings, waste of time, and expense, which are not yet in practice overcome by the best of them.

Attempts seem to have been made to use oxides or sulphates of some oxidizing or easily oxidisable material, by mixing them up with grease or some other vehicle to keep them together, into a sort of paint or compo, and then smearing or plastering them over the whole under-water portion of the hull of the ship, the avowed intention being that the water and its action shall cause the material to exfoliate, and thus wear off and keep the bottom clean. A little consideration of the subject would have shown that a far better, more common-sense, and practical plan would have been to have found a metal that would do all this, attach it to the ship, and have done with it, as by this means far greater durability would have been attained, and less likelihood of the protecting surface being displaced or washed off by the friction of the ship when passing through the water.

It has been proposed to use oxide of zinc, or metallic zinc in powder, mixed with oil, to paint the bottoms of iron ships, in order to prevent oxidation and fouling; but it seems to have been forgotten that oil acts as a non-conductor, and will prevent the very galvanic action which is so necessary in order to obtain the advantages which zinc cannot fail to give when applied to iron.

Increased zoological and chemical knowledge cannot fail to show that "poisoning" is an absurdity, and that success is most surely and certainly obtained by applying the zinc in its *metallic* state in the form of *metal sheets* to the hulls of iron ships.

Of course, because this has not been done before, there are not wanting those who express their firm conviction that it cannot succeed, and will not act in the manner described, especially as when applied to *wooden* hulls it is not so good as copper or yellow metal; but a very moderate amount of chemical knowledge shows that its application in a successful manner is a mechanical question, and this once overcome, there need be no anxiety as to its satisfactory operation.

Glazing, painting, plastering, poisoning, pickling, and all sorts of schemes, possible or impossible, seem to have made no difference, have engaged the attention of various persons, though but few would appear to have studied the subject so as to thoroughly comprehend the principles and action necessary to be obtained in order to secure success. Due consideration of the subject would have shown that a permanent surface presents a favorable condition for the growth of barnacles, zoophytes, weed, &c., and that although poisoning them might be good in theory, it would be inadmissible in practice, first, because it would be found extremely difficult to ensure its adherence to the iron hull; and next, if it did adhere at first, its duration in an active state over the whole surface might be taken as highly problematical, and its easy removal, if merely smeared on, could not fail to be a serious objection. And, above all these, comes the greatest objection of the whole, which is, that from none of the barnacles, polypi, &c., *holding on by their mouths*, it is pretty evident that the effect of the poisoning process, so far as these gentry are concerned, must be set down as *nil*.

Amongst the many materials for preventing fouling and corrosion of iron ships which have had patents taken for their use or been experimented with, will be found silicates, quicksilver, plumbago, gutta percha, asphalte, shellac, guano, cowdung; now comes a powerful compound consisting of "clay, fat, sawdust, hair, glue, oil, logwood, soot, &c., mixed," to be plastered on the ship's bottom; then we have "emery, shellac, and castor-oil;" next "pitch, tar, and shellac;" next comes another peculiar compound, "baryta, litharge, arsenious acid, asphaltum, oxide calcium, and creosote;" then another, "Burgundy red earth, grease, lime, unburnt earthenware, chalk or Roman cement." Next follows a very curious composition consisting of "grease from boiled bones, kitchen stuff and butter without salt, mixed with poisonous matters;" now we have the grand *chef-d'œuvre* of the whole, which is thus described, "Sugar, muriate of zinc, wax, soap, calcareous stones, phosphate of soda, sulphate of zinc and copper, and the syrup of potatoes or sugar with powdered marble, quartz, or felspar." The last one which will be noticed consists of "asafœtida with pitch, tar, resin, and turpentine smeared over the bottom, and then coated with paper or cloth." Who will say after all this, that poisoning and physicking have not had a fair chance?

It is admitted that even with the most successful of the "anti-fouling" and anti-corrosive" paints or compositions, which are now before the public, the vessel ought to have a docking and "top-dressing" at the end of six months, though it is said that some have gone so long as nine months without being "top-dressed."

In January, 1848, the iron steamer "Megæra" had the "anti-fouling" compositions of eight makers applied to different parts of her hull, and on examination after running the usual time, the following results were reported by her captain:

1. *Lee's composition.*—As foul as red lead, hard when scraped, but there was *corrosion* in spots.

2. *Moresby's composition* (aloes and red lead).—Could not be distinguished in any way, either in colour or cleanliness, from red lead.

3. *Clark's composition.*—No. 1. Foul, rusty appearance outside, and *corrosion penetrating into the plates.* No. 2. Very foul, and *much corroded.*

4. *Ince and North's composition.*—Barnacles and grass as on red lead, but no corrosion, and when scraped the composition appeared perfect.

5. *Hay's composition.*—*Much corroded* and foul.

6. *Chanter's or Weddersted's.*—No. 1. Foul and *much corroded.* No. 2. Appearance clean and without corrosion, excepting upon after part of plate; but when struck with a hammer it scaled off, showing that *corrosion had taken place beneath the paint.*

7. *Grantham's composition* (one part tallow, two resin, one sulphur).—Foul, and *very much corroded.*

8. *Parker's composition.*—*More corrosion,* barnacles, and grass, than upon red lead.

The 'Times' of September 23rd, 1864, stated that the "Achilles" about January, 1864, was payed with "Hay's compound," and afterwards lay in Chatham harbour for nine months; at the expiration of which time she was examined and found to be *covered with weed and barnacles,* some of the former measuring *two feet in length.*"

On the 6th of October, 1864, the 'Times' remarked, "It should, however, be taken into consideration by those who are keenly watching the approaching performance of the "Achilles," that as much probably as *two knots per hour* must be allowed in her rate of speed, in consequence of the foul state of her bottom."

The 'Times' of Nov. 23rd, 1864, contained the following particulars relating to the floating fire-engine in Chatham Harbour:—"On being hauled up on the slip the condition of the bottom of the vessel afforded another proof of the worthlessness of all the so-called 'anti-fouling' compositions hitherto in use in the Royal Navy for preserving the iron plating, and at the same time preventing the accumulation of animal and vegetable matter on the bottoms of iron ships. Only a few months ago the submarine portion of the floating fire-engine was carefully payed over with the most approved of the many mixtures hitherto brought under the notice of the Admiralty; but so far from the composition having the desired effect, the bottom when examined was found completely covered with a field of grass and seaweed, the latter from four inches to upwards of a foot in length; while there was an unusually large accumulation of barnacles and other mollusca, the greater portion of the composition being eaten away, leaving the iron plates completely exposed."

That the repulsion of barnacles and seaweed and the maintenance of the ship's bottom in a clean state may be accomplished, it is necessary that the surface of the metal employed should exfoliate, and where this action is obtained the barnacles, mussels, and other fouling matter have no sooner obtained a hold than they are at once detached, together with the surface on which they have "squatted" or attached themselves, the process being an "action of ejectment," but of a far more certain, summary, and rapid character than the legal operation known by the name.

The common belief has been that copper and yellow metal sheathing kept clean and free from fouling from their poisoning the barnacles, weeds, &c., by the verdigris which the water caused to form on the surface; and when in 1765 H.M.S. "Alarm," the first vessel that was coppered in the Royal Navy, was found to have her copper bottom perfectly clean after a four years' trial, the success was attributed entirely to its poisonous character.

Sir John Hay said, at the Institution of Naval Architects in 1866, that "there was a sort of belief that one of the advantages of copper consisted in the fact that the verdigris destroyed the marine animal or vegetable substance which attaches itself to the ship's bottom, and so causes fouling; but the fact is, that the action of copper in keeping a ship clean is mechanical. We find that copper oxidises in parallel layers, and that it sheds off in very thin layers, so that the substances which cause the fouling of the ship attach themselves to the copper, and having attached themselves to the copper they lose their hold, and are detached by the continual exfoliation of the copper."

Admiral Sir Edward Belcher, C.B., remarked, respecting the necessity of the galvanic action, "As to the adhesion of mollusca to ships' copper bottoms, where there is no such action going on, and where the vessel is not rapidly forced through the water, the case of the 'Ardent' at Bermuda furnished the finest specimens; and most magnificent specimens of different shell-fish, *spondyli*, were afterwards sold, some as high as ten guineas each."

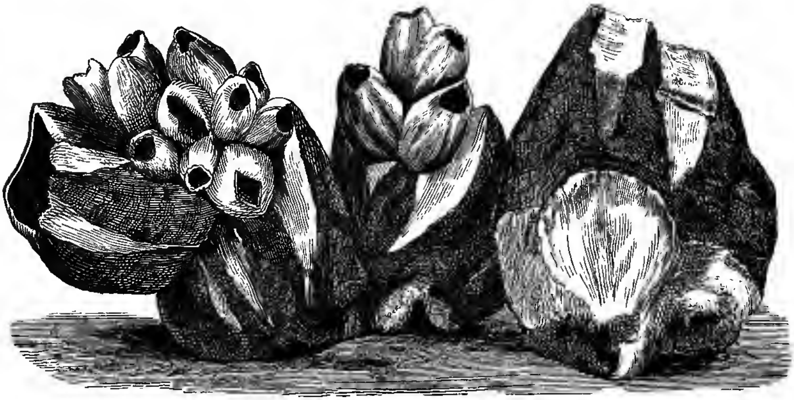
It has been remarked somewhat dogmatically, that "for protecting iron vessels against corrosion and the adhesion of barnacles, the use of a poisonous paint is in all cases indispensable, and this paint must be slightly soluble in water, else the poison in it will be of no avail."

Mr. John Bourne, in the 'Artizan' of 1844, considered "marine glue" preferable to paint for coating the bottoms of iron ships, and "by mixing this substance with arsenic previous to its application, the adhesion of weeds and barnacles *will be effectually prevented.* In fact, an arsenical paint of any kind is an *effectual* *remedy* against these adhesions, the arsenic being destructive of both animal and vegetable life."

Experience, however, has proved most satisfactorily the fallacy of this statement, and daily increasing proofs are given of its utter inutility, even when tried under the most favorable circumstances and conditions, for producing this "indispensable" effect; whilst at the same time satisfactory proof is given of how completely the action of metallic sheathing in keeping clean is misunderstood even by those who have professed to be the greatest authorities on the subject.

Professor Wilson is said to have proved in a very satisfactory manner the utter inutility of the "poisoning" process, and this not by theory but practice. In order to obtain the true result, whether for or against, he took the most subtle-known poisons and mixed them with ordinary paint, and smeared some wood and iron with them. Barnacles soon grew to a large size on these paints, and he then took some of them off, boiled them, and gave them to several animals, which were poisoned by the mess. This would seem to show that such nuisances are very tenacious of life, and able to thrive on what proves to be the destruction of less tougher and useless animals, giving at the same time a rather severe blow to the "poisoning" theory.

Fig. 1.



The author has often tried to eat the oysters which are dredged up on the Cornish coast, and are well known from their beautiful green colour; but he has invariably found them to be so strongly impregnated with copper, to which their colour is owing, as to be positively uneatable. He has also in his possession a photograph from a large bunch of barnacles (of which Fig. 1 is an exact copy, full size), which were taken off the *brass* screw propeller of H.M.S. "Phœnix" whilst stationed on the coast of Africa, where they had flourished well and grown to a large size, in spite of the "poisonous" character of the substance to which they had attached themselves. It is well known that in the heated water of the tropics the corrosion or oxidation of any metal proceeds with greater rapidity than in the cooler waters of the temperate zone; therefore it is but fair to assume that the *brass* screw would have been covered with a sufficient amount of verdigris to have given the poisonous properties a fair chance of acting.

Mr. Mallet, who, amongst other things, had tried his hand at anti-fouling compositions, says of them:—"They are at best but mere palliatives, for it is a fact that they all do foul after a time longer or shorter, over the whole surface. The stuff gets stripped off by the washing of the water or accidentally, and as soon as that takes place the remaining portion begins to get coated with a thin film of carbonate of lime deposited from the lime in the sea-water; and the moment that deposit takes place the surface becomes a fit nidus for the lower marine animals and vegetables, and then fouling goes on. We therefore come to this conclusion—that some better method is wanted for the protection of iron ships than is afforded by any chemico-mechanical method of coating yet proposed."

It is the rule in many cases that ships coming from a foreign station, and which have been at sea sufficiently long to get tolerably foul, are frequently "hogged" before arrival, and are docked during the night, and gangs of men are put on to scrub down the under-water portions as the water recedes, so that the weed, &c., may be carried out by the rush of water from the dock. In the morning the ship is examined, and found to be "exceedingly clean and free from fouling," or else "had not a bit of weed an inch in length on her bottom," nor more than "one solitary barnacle." Such facts can be easily ascertained by any one who will take the trouble, but are not the less true because they may be classed amongst "things not generally known."

The 'Times' of the 18th of November, 1864, says:—"Notwithstanding the numerous descriptions of what are termed anti-fouling compositions which have been submitted to the Admiralty, no discovery appears yet to have been made of a preparation for effectually preventing the accumulation of animal and vegetable matter over the hulls of iron vessels. Although the bottom of the iron frigate "Achilles" was coated over with the anti-fouling composition of Mr. Hay, the Admiralty chemist, before her launch, so foul had the bottom of that vessel become while in Chatham harbour, preparing for sea, that in the run from Chatham to Devonport her speed fell off more than three knots an hour from her steaming rate on the occasion of her official trip to the Maplin Sands."

In regard to the latest experience of "anti-fouling" and "anti-corrosive" paints, compositions, &c., the result of eighteen months' trial of some of the best of them as tried on H.M.S. "Valiant," is thus given in the 'Standard' of January 10th, 1867.

"The 'Valiant,' armour-plated ship, 24 guns, 4063 tons, 800 horse-power, for some time placed in the steam reserve, was yesterday hauled into dock at Portsmouth, after having been made for the past eighteen months the object of experimental trials of various kinds of anti-fouling paints. The state of her hull when thus exposed was such as to convince any unbiassed person of the complete inefficiency of all anti-fouling nostrums, and to prove the absolute necessity for sheathing iron ships with a metallic covering of zinc in the same way as wooden ships are sheathed with copper. In August, 1865, she was painted below her water-line on the whole of the starboard side with Gisborne's mercurial varnish; on the larboard side the bow quarter with Mr. Hay's composition, a washing of oxide of copper, we were told, over a coating of marine glue; the stern quarter with that of Mr. Rowett; and a small portion of the midship section with a sort of enamel by Mr. Jennings. Mr. Gisborne's process is to first coat the iron skin of the ship thickly with red lead and then to wash over with another kind of red paint, the main base of which is crude mercury. The action relied on, therefore, seems to be in some sort galvanic, but of so weak a character that it is impossible it can be compared with the more energetic and safe action of an absolute covering of zinc sheathing as has been proposed and successfully experimented upon by Mr. Daft, C.E. Even the slight voltaic action of the mercury would seem to have been sufficient to prevent a high degree of fouling, for Mr. Gisborne's portion of the hull showed a cleaner surface than any other, although this was far from smooth, and was sprinkled about with considerable fields of short fine weeds, with here and there clusters of shrubby algals, interspersed with considerable colonies of living mussels. Where the anchor had chafed against the skin of the ship and at other similarly bared spots the corrosion of the iron was very manifest. Mr. Hay's portion was the next cleanest in appearance to the eye, but the surface of this part of the ship seemed all streaked about as if it had been 'hogged.' It must not be thought, however, that this part of the hull was by any means clean. At regular intervals of about twelve or fifteen feet apart were large bunches of the long ribbon-like laminariæ, the cause of which was assigned by the workmen in the dockyard to the shoring of the vessel in the dock previous to her long mooring in Portsmouth harbour, these patches of seaweeds being on the sites where the ends of the shores had rested, and at which some chafing of the composition had possibly taken place. How the iron plates beneath this composition have stood the trial no one, we suppose, yet knows; but the extreme danger of applying copper in any form or connection is too well known not to make it a matter of surprise that the Government should permit the trial of any compound of that metal upon the hull of so large and so costly a ship. Of the state of Mr. Jennings's enamel it was difficult to judge, the portion covered with it being small and lying low down under the ship's bottom. The water had not been sufficiently emptied out of the dock when we left the dockyard to enable us to judge with certainty. So far as could be seen it looked as if thickly coated with slimy matter. But the quarter assigned to Mr. Rowett was in a state of the most luxuriant growth; thousands of olive tangles hanging down for a length of six or seven feet, and all the general surface of the hull being a dense mass of animal and vegetable parasites. We have rarely seen anything so bad."

The following from the 'Times,' January 11th, 1867, gives their statement of the results of these trials:—"The 'Valiant,' iron-clad frigate, in dock at Portsmouth, was yesterday surveyed by the officials of the yard, to enable them to prepare the requisite official reports on the state of the several experimental compositions with which her hull below the water-line has been coated, to preserve the iron of the ship's bottom, and to prevent fouling. *The primary requisite qualifications for all paints or patented compositions paid over the bottoms of iron ships is necessarily the 'preservation' of the iron.* The secondary and much less important consideration is the efficient action of the paint as an anti-fouler. The 'Valiant' was docked at Portsmouth on the 9th of August, 1865, and remained in dock until the 11th of September, thus giving ample time to the various compositions which had in the meantime been paid over her bottom to become thoroughly dried, before she was again placed in the water. The entire starboard side of the ship was coated with Gisborne's anti-fouling mercurial composition, laid on in four coats upon red lead. The port bow to nearly amidships was paid over with the 'Hay' anti-fouling composition, laid on upon a coating of the 'Hay' preservative varnish. Amidships, from the keel upwards, was a patch of Jenkins's enamel, and the remainder of the vessel below the water-line aft was coated with Rowett's anti-fouling paint, both the Jenkins and Rowett being laid upon the Hay preservative varnish. The vessel having been afloat, but in still water, at harbour moorings, for sixteen months, afforded a very fair opportunity for judging the relative merits of the various competitive compositions; but this cannot be completed before the bottom of the vessel has been scrubbed, and the exact effects of the damage from the anti-fouling mixtures upon the iron of the ship's bottom, if there be any, has been fully ascertained.

At present the Rowett patch of composition is closely covered with an average depth of six inches of polypi and sea-grass near the water-line of as many feet in length. The Jenkins patch was nearly as bad, and *both give strong evidence of corrosion,* the real nature and extent of which will only be ascertained when the ship's bottom has been scrubbed. The Gisborne composition has kept the starboard side of the ship moderately clean, but the red-lead under-coating is decomposed, and *the rivet-heads give evident signs of corrosion.* Electric currents have been at their dangerous work, but this Mr. Gisborne ascribes to the fact of red lead having been applied to the bottom of the ship by Admiralty order, instead of the peculiar varnish recommended for the purpose by Mr. Gisborne. Mercurial paints may possibly be perfect as anti-foulers, if laid on a proper underlying protectral varnish, such as is used by the Admiralty chemist, but mercurial paints laid on red lead might also possibly destroy the bottoms of the iron ships of Her Majesty's navy. The Hay composition on the ship's port bow only remains to be noticed, and this can be done very shortly. The fouling is very slight, although a trifle in excess of that on the Gisborne paint. The composition appears perfectly sound in every part, and there is no corrosion excepting where abrasion has taken place from the chain-cables or from the dock shores. As, however, we have already observed, the ship's bottom must be thoroughly cleaned of the polypi, sea-grass, and other adhesive substances, before any correct estimate can be formed of the peculiar qualities, favorable or otherwise, of the respective compositions. Connected with this docking of the 'Valiant' has been the trial of a patent scraper and revolving brush, the invention of Mr. Harrison, of Liverpool, for scraping and cleaning the bottoms of iron ships at times when it may be advisable to save the expense and delay of docking, or when docks may not be available. The scraper and the brush were both passed over two strips of the 'Valiant's' starboard side previous to her being placed in dock, the operation being exceedingly simple, and the action of the scraper or brush on the ship's bottom certain. On examining the 'Valiant's' bottom in dock yesterday, those parts over which the scraper or the brush had been passed were perfectly clean, and the results of the trial of the small machine—for it is small in consideration of the work it does—was thus far most satisfactory."

It has been said that the requirements of a shipowner or merchant in a vessel should consist of the following points:

1. Strength combined with lightness.
2. Great stowage capacity.
3. Safety.
4. Speed.
5. Durability.

6. Economy in maintenance and repairs.
7. Cost of ship.
8. Draft of water.

Now, assuming that the ship has been constructed in iron, to obtain all of these in the fullest manner, at the commencement, experience has shown that unless special attention has been directed to the overcoming of the two serious evils of fouling and corrosion, and special means taken to render their prevention certain, that either of them are sufficient to speedily do away with the beneficial results which had been otherwise obtained; but there is also this important and serious drawback if these points have been neglected, which is, that both corrosion and fouling invariably accompany each other, and combine to render the destruction of the ship a comparatively speedy operation.

In the report of the Committee on Dockyards and Basin Accommodation it is remarked, that on foreign stations the provision of dock accommodation has become almost indispensable in consequence of the conversion of the navy into a steam navy. In former times it was the practice to heave ships down in careening wharves when in want of repair; but this expedient is not resorted to in the case of steam vessels, as their machinery would be deranged by the operation; and consequently, on stations where there are no docks of sufficient size, it is necessary to send them home whenever their bottoms require to be either cleaned or repaired. During their absence from their stations the cost of wages, victuals, coals, and of wear and tear, is a *dead loss,* and this loss would be of constant recurrence in the case of iron ships, as it is necessary to dock them for the mere purpose of cleansing their bottoms *at least* four or five times in the course of the ordinary duration of a commission.

On this it has been remarked that "the proposal to build docks on all our distant stations for our men-of-war to be cleaned in does not meet the question, for the intention of sending a vessel from this country is hardly for the purpose of putting her into dock for a fortnight immediately on her arrival at her cruising ground. The building of docks is, besides, only half the affair; being built, they require fortifications, and a strong force to prevent their being destroyed, the existence of a dock alone making the destruction of it an important blow as long as vessels are dependent on it for remaining efficient. They must be defended by regular fortifications, for the experience of what has taken place in America (if it were required) shows us how detached, irregular works can be passed by iron-clads, and a ship or even a boat's crew of the enemy might surprise a vessel helpless in dock, and destroy her, and an enemy's squadron, should the place not be sufficiently strong, gives the alternative of the destruction of the town, or of the docking and coaling of our own ships. The docks may do very well for peace, when it is not really of so much consequence whether a cruiser is a knot or more faster, but, excepting at enormous cost, they will not meet the requirements of war."

The "Megæra," when taken into dock after eight months from the former docking, was found, in the words of her captain, in an extremely foul state, in fact, like a mussel bed; and in three days after the smell from the decayed fish was almost unbearable. Prior to going into dock her steerage was very much affected, and her speed had fallen off from two and a half to three knots, with a strong gale, three reefs in topsail and reefed foresail, scudding with the screw up, she only averaged seven and a half knots, when, if her bottom had not been foul, she would have done ten and a half or eleven.

This ship burns, at full speed, forty-five tons of coal per day, and at an average speed of ten knots she should do with the above quantity 240 miles; but as it is shown that her speed was diminished three knots per hour, that quantity would only take her 168 miles. Taking coal at £2 per ton on board, her cost for coal alone is £90 per day, whilst the cost of the coal wasted by the bottom being foul amounts to £23 per day; whilst during the time of war, when the price of coal would be much higher, and other things as well, the loss would be correspondingly heavy.

It has been found, from accurately testing the steamers of the City of Dublin Steam Packet Company, which carry the mails from Holyhead to Kingstown, that during the summer, in about two months after leaving the graving dock, their speed uniformly falls off so as to increase the length of the passage ten to fifteen minutes, or about half a mile to one mile per hour.

The importance of maintaining an undiminished rate of speed, both under steam and under canvas, but especially under steam, will be seen when it is remembered that the iron-clads "Resistance" only carries four days' coal at full speed, the "Valiant" three and one third days' coal, and the "Warrior" five days' coal.

It is and must be a humiliating reflection to us all, that after an expenditure, to say nothing worse, of just *seventy millions sterling* by the late naval administration, that we have no iron fleet, no guns; and that those iron vessels which we have, and on which so many millions have been spent, are useless after six months' duty afloat, on account of the fouling of the hulls and the rapid deterioration of their speed. What they might be fit for after six months in the tropics may be readily imagined from what has occurred in our own harbours.

The enormous evils of fouling and corrosion still exist in all these ships in full force; and both are not a little increased by ill-judged attempts at prevention, the most glaring of which is that of a wood sheathing covered with copper, the serious damage caused by which has been amply and, unfortunately, too frequently, proved in our iron-clads.

In 1864 the late secretary of the Admiralty, when bringing forward the naval estimates, spoke in the strongest terms of the difficulties caused by the fouling of iron ships; but it does not seem to have occurred to any of them, although deeply impressed with the evil, to offer a premium, reward, or other tangible encouragement for a practical and efficient remedy, nor to profit by the well-proved principles of chemistry in regard to the proper materials to be employed for overcoming the difficulty.

The French Admiral Paris, so well known from his scientific investigations and his dictionary of technical terms, says, "When one thinks of the number of steamers on the seas, of the thousands of tons of coals they burn, one cannot help seeing that the wealth of the whole country is being spent in this obstacle, the overcoming of which would produce enormous profits. In the time of war it will often be heard that one vessel has been captured because six months had elapsed since she had been painted, while the victor had perhaps left the dock only three months previous."

There cannot be the slightest doubt that the result of building iron-clads with iron hulls, which are not and cannot be sheathed in a proper manner, so as to keep clean without damaging the iron, will render it perfectly impossible in war time to employ such vessels on distant stations and for long voyages, or even to use them at all on stations where similar vessels, but provided with properly sheathed hulls, are kept by other countries who at that time may be our enemies.

The Right Hon. Sir John Pakington, Bart, M.P., President of the Institution of Naval Architects, and First Lord of the Admiralty, remarked at the session of 1866, when referring to the fouling of iron ships and Mr. Reed's remarks on their not being sheathed, "It is a fact which he has just admitted, and which we must all learn with very great regret, that at this moment all those splendid and costly armour-covered ships which have been built for the navy during the last few years are still under the great disadvantage of having no copper over their bottoms."

Mechanical means for clearing off the fouling whilst the ship is afloat, can only be *very partial* in their action; but however effectually they may do their work, they introduce a very dangerous and serious evil, one the importance of which cannot be overlooked, and that is, the removal of the paint, coating, or anti-fouling composition applied to the under-water portion, as must infallibly happen to some portion of the hull, by which the bare iron is at once exposed to the action of the sea-water, and the corrosion caused thereby; and also to the increased liability of fouling which bare iron always possesses, and this must remain until the ship can be docked, no material being in use which can be applied under water.

It is stated in one of the plans or systems promulgated for cleaning the bottoms of ships when afloat, that where the ordinary brushes will not remove the fouling, brushes of *wire* are to be employed, and the action of these upon the paint or other coating can hardly be doubted, and that its speedy removal by such an operation would be readily accomplished; this may be called getting rid of *fouling* to promote corrosion.

It has been well remarked that the "remedy would become worse than the disease," as not only would the fouling be removed, but the paint or other protecting material also, and the surface of the iron hull, be left exposed to the corrosive or oxidating action of the salt-water.

An American newspaper extracts from the 'Baltimore American' some account of the operation of cleaning the bottoms of the monitors, written by its correspondent at Port Royal. He says that the chief diver, Waters by name, is so used to this work, that he has become almost amphibious, remaining for five or six hours at a time under water. The work is very arduous. The diver sits upon a spar lashed athwart the bottom of the vessel, so arranged as to be moved as the work progresses, and, with a scraper fixed to a long handle, works on both sides of himself as far as he can reach. The mass of oysters that become attached to the iron hulls of one of the monitors even during one summer here is immense. By actual measurement it was estimated that 250 bushels of oysters, shells, and sea-grass were taken from the bottom of the "Montauk" alone!

Mr. Grantham, in his book on 'Iron as a Material for Shipbuilding,' gives a sketch and description of his mechanical scraper for cleaning the bottoms of iron ships, which possibly might act in the case of flush or carvel-built ships; but he omits to explain or describe how it is to be used in vessels built on the "in-and-out" strake system, and shows it as applied to the bottom of a "carvel"-built one.

The 'Mechanic's Magazine,' in the first volume for 1862, contains the following remarks:

"The question of the fouling of iron ships has not attracted the attention of the Admiralty and of scientific men as it deserves; and if some remedy be not found for the evil, it becomes questionable whether iron ships are improvements on wooden ones.

"We find that the bottom of the 'Resistance,' when placed in dock at Portsmouth on Tuesday last, was in an extraordinary condition, in fact, it was foul as if the vessel had gone on a long commission, instead of being on the home station.

"The entire bottom was coated with weeds and grass; patches of mussels were on the port side, together with a good sprinkling of barnacles.

"On the starboard side the barnacles extended from stem to stern, with weeds and grass in some places three feet in length.

"The mussels extended fore and aft, with barnacles as large as a child's head.

"It is, in fact, surprising how such foulness could have accumulated in so short a space of time. It was not because precautionary measures had not been taken. The ship's bottom was originally coated on each side with various protective compositions. On one side the composition was entirely destroyed, and patches of rust, more particularly under the quarter, had eaten their way through."

Mr. Leo Daft makes the following remarks on preventing the fouling and corrosion of iron ships:—"To ensure a hull from fouling it is absolutely necessary that it should be composed of, or sheathed with, a metal that will by *galvanic action* PEEL or FLAKE off as zinc, copper, or yellow metal. Paints and compositions are utterly worthless in this respect. Enamels, glass, and vitreous substances are equally and utterly useless for keeping a clean hull at sea. Barnacles, crustaceous animals, and weeds will fasten with avidity upon *non*-oxidizable material, and hold with such firmness that they can only be removed by the chisel and hammer, or by immersion in fresh water. Abundant proofs of this exist in every direction around us. The smoother and more even a vitrified or similar surface is, the greater is the certainty of its fouling and its difficulty of removal, whilst the foul state of bottles after immersion in the sea show how much resistance to fouling they offer."

"An iron ship should be sheathed with zinc because it is the only metal that stands in a distinctly *positive* relation to iron, and is, therefore, the only metal which cannot injure iron by galvanic action. Long experience has proved zinc to be an excellent sheathing on wood, but its great durability and sluggish exfoliation have been known, under trying circumstances, to allow of a slight accumulation of weeds, &c., which is entirely overcome by metallic contact with the iron; for by that contact slight galvanic action is established, PROTECTING THE IRON, but increasing the exfoliation of the zinc sufficiently to render the accumulation of animal or vegetable life, however small, impossible; while the action is not so vigorous as to make any serious difference in its durability. Therefore sheath an iron vessel with ZINC, and you have a chemically-protected hull, and a perfectly clean surface at much less cost than copper or yellow metal, with no risk of corrosion of hull from galvanic action, and with equal durability."

The 'Times' of July 3, 1865, speaking of the "Great Eastern," contained the following:—"The foul state of the "Great Eastern's" bottom, coated with a six months' growth, at least, of mussels, will greatly impede her steerage way, as they certainly will not drop off before she reaches Dover."

The 'Times' of January 28th, 1867, relates of the "Great Eastern" that "four years back she was coated," and that when examined on the gridiron a few days before the date of the remark, was found "completely free from barnacles or weeds;" but admits that "some small mussels were found adhering to her bottom, but these are easily detached; and the ship everywhere presents a most satisfactory appearance." It states that one portion "is now found to be covered with *soft rust* more than *half an inch* (!) in thickness;" but *this* part of the vessel, of course, was not coated with any composition.

Winter, being a period when the growth of weeds, barnacles, and other fouling annoyances is generally torpid, or at least very inactive, cannot be taken as a proper period of the year in which to try the efficiency of any anti-fouling preparation. This can only be properly done during the spring and summer months, when vegetation commences, increases, and is maintained with great vigour; and as at this season the increased temperature of the water is most favorable to the development of these annoyances, this must be looked on as the proper course to be followed. Trying prevention where no cause exists, cannot for a moment be either sensible or useful.

The 'Engineer' of June 22nd, 1866, contains the following remarks on desiderata in iron ships:—"In the midst of the sort of vain satisfaction with which the application of iron in large quantities to shipbuilding is mostly regarded, it is often forgotten that at least two most important problems in iron ship navigation yet wait for a generally accepted solution. The first of these is the prevention of the local attraction of the hull on the compass; the second would consist in some mode of keeping the metallic bottoms sound and free from the submarine organic growths which so materially affect the speed of the vessel."

One point should always be kept in sight, always acted on, and never forgotten, which is, that all our ships should be made as efficient as possible, and no means left untried by which sufficient promise of success is given; and this is more particularly the case with our huge and costly ships of war, costing enormous sums for hulls and engines, and also for wages, coals, stores, &c., and as yet exposed to the damage and loss caused by fouling and corrosion, for which *none* of the remedies tried have *in any way* proved an efficient antidote.

Failures often prove the cause of ultimate success, inasmuch as they necessitate a proper study and investigation of the causes which lead to them, and these when once arrived at may be said to afford the key to their remedy or prevention if common sense be called into requisition and aided by some practical knowledge and experience on the subject.

To obtain a simple, practical, and efficient mode of attaching plates of metal or sheathing to the hulls of iron ships, without increasing the cost of construction or damaging the hull of the ship, has been a desideratum ever since the introduction of iron as a material for construction; and its rapidity of fouling and corrosion gave unmistakeable proofs of the vital importance of getting over these hitherto most formidable difficulties.

Although many plans more or less ingenious or impracticable have been patented or proposed of late years, there can be no doubt that the plan invented and patented by Mr. T. B. Daft, C.E., is the one which fulfils all the various requirements in the fullest and most satisfactory manner, and this, too, without incurring the slightest drawback, difficulty, or disadvantage, by its employment.

The value of such an invention, especially as it is of a thoroughly practical and efficient description, may be well estimated from the following remark of Captain J. H. Selwyn, of the Royal Navy, that "the problem of keeping a ship's bottom clean is one of the very greatest importance."

# CHAPTER VI.

## CORROSION.

Corrosion, or the gradual destruction of the iron hull of a ship by the action of the sea-water, is a most formidable and serious evil, as it involves the gradual weakening and destruction of the ship, and the extent of its insidious and certain action is not immediately discoverable unless a ship be docked and the hull carefully and minutely inspected. The *discovery* of its action does not, unfortunately, prove its *prevention*, for although every precaution may be taken to rectify the damage where it may be discovered, it will *not* prevent this fatal action going on somewhere else; thus, in a short space of time, a ship may be so weakened and injured over a considerable portion of its hull as to be far from seaworthy, and there can be no doubt that many an iron ship has foundered from the ill effects of this action, and from its having proceeded more rapidly in some portion than had been the case elsewhere.

The corrosion of the iron hull of a ship is admitted to be of great moment; to protect the plates is of the greatest importance. Paints are of little use, for though above water, if the paint should be rubbed off, it can be laid on again, under water this cannot be done without docking or grounding the ship; consequently the iron must be left exposed to this destructive action until an opportunity can be afforded for so doing. It is a well-known fact that all parts of a ship and each plate in the hull do not corrode equally or in a similar manner, for which reason it is difficult to find out its extent, except by a minute and careful examination over the whole extent of the hull both inside and out. Iron plates, for example, will corrode in large patches several inches in diameter, others in a number of small holes or pockmarks, eating deeply into the plate and forming small pinholes through it; in other cases corrosion will attack the rivets, and the plates will be comparatively free; but be this as it may, the serious and alarming character of the disease cannot for a moment be doubted, nor the importance of finding and applying a remedy, or, better still, a means of prevention.

The corrosion of the iron hull of a ship is due to two causes: first, the destructive action of the salt and other matters contained in the water, which cause the oxidation or gradual destruction of the iron; and secondly, galvanic action caused by the presence of copper, yellow metal, or other material of greater power in the galvanic scale, which causes the action set up to be concentrated on the iron composing the hull of the ship, and results in its far more speedy destruction and injury than when exposed to the action of simple oxidation, added to which it is far more difficult to counteract.

The first, or the action of the sea-water on the iron, is increased by the presence of fouling and the decomposition of the animal and vegetable matter of which it consists, the products of this decomposition greatly assisting the action. Mr. Hay, the Admiralty chemist at Portsmouth, stated at the Institution of Naval Architects, in 1863, that "The decomposition of animal matter which takes place whilst attached to the bottom is most destructive to the iron."

The oxidation of an iron hull does not always proceed with regular rapidity, nor does it confine itself to any particular portion, but varies in both according to circumstances. For instance, in fresh water, certain conditions exist which are not found in sea-water, and also the difference of temperature is found to have a great influence on its rapidity of action. In sea-water it is generally found to be much more active, from the variety of substances contained therein exerting a much more powerful chemical action, and this increases greatly with the temperature of the water in which the ship floats.

Captain J. H. Selwyn, R.N., having had some experience on the coast of Africa of the rapidity of corrosion in the heated water of the tropics, says, "An iron rudder in a ship which I commanded was so hung by the constructors, through want of knowledge of galvanic action existing at that time, that it was hung between two metal points in connection with the copper of the ship; that action was so intensified that in eight months there was not one ounce of the iron plate of the rudder which was not decayed, and which was not in the form of red oxide. That is a fact which shows that galvanic action is capable of going on."

The 'Times' of the 18th November, 1864, stated that "When docked at Devonport the bottom of the "Achilles" iron-clad was found to be not only foul, but to have many of the plates left completely bare of the composition, and *corrosion* had in many cases *eaten away* the plating to the depth of from *one sixteenth* to *one tenth of an inch*"!

The insulation or prevention of corrosion of armour-plates and the iron hulls of ships has, up to a very recent period, baffled every attempt that has been made to obtain such a desirable end; but experience has shown that this has resulted more from the want of a thorough comprehension and study of the principles involved in corrosion than in any practical difficulty in doing it when they are understood.

Nothing in the shape of a plaster or composition has yet been discovered to effectually guard against the destructive action of corrosion, or to prevent the fouling of the bottom of iron ships for any length of time—nine to thirteen months being the longest period any of the compositions will last on a ship's bottom without renewing; but requiring "hogging," however, during that period. And a little consideration of the subject should show that neither of these is the best plan or system by which it is most likely to be obtained.

The following examples illustrating the rapidity and extent to which this evil of corrosion extends will amply prove the necessity of at once taking means for preventing it.

The "Grappler," in less than three years from the date of the order for her building, was so corroded that a hole of five inches in diameter was discovered in her bottom!

The "Jackal" was coated with red lead in May, 1847, and when docked in April, 1848, the plates and rivets were found corroded to such an extent that it was necessary to remove some 200 defective rivets, and to punch holes in the corroded parts of the plates, and plug them up again where they had suffered most from corrosion.

The "Antelope," which had been to the coast of Africa, was docked on her return, fifteen months after her former painting, and the iron was found much corroded and many rivets had to be removed and replaced.

The "Harpy," which had been four years on the south-east coast of America, when examined on her return, was found to have the plates much corroded; flakes from 4 inches to 6 inches in diameter, and $\frac{3}{8}$ths of an inch to $\frac{1}{2}$ an inch in thickness, were removed, and numbers of rivets had to be replaced.

The "Bloodhound," on her return from a foreign station, was found to have corroded so extensively as to require a new bottom, which was given her.

The "Jackal" founded at Greenock, from the corrosion having eaten through the plates apparently unnoticed.

In 1863, some of the plates in the "Fairy," H.M. screw-yacht, were found to be *eaten nearly through*, the mischief having progressed unknown and undiscovered!

The "Myrmidon," iron steamer, belonging to the Royal Navy, was found, when at Fernando Po, some years since, to have her bottom plates so corroded that they were said to be "eaten through like a colander," and the ship was in consequence condemned.

The 'Mechanics' Magazine,' of January 5th, 1866, states that "a discovery has been made at Toulon, where the iron-plated frigate 'Provence' is undergoing repairs, which shows the danger that menaces the entire iron-coated fleet of France. The 'Provence' was fitted out for sea only *fifteen months* since, and already a great number of her plates were *nearly consumed with rust.* The Director-General of Naval Architecture is of opinion that if a composition be not discovered to prevent the action of rust, the iron-plated fleet must be renewed *every five years!*"

Chemical knowledge shows it to be highly dangerous to allow copper in any shape to come in contact with the immersed portion of the iron hull of a ship under any circumstances. It is totally useless in keeping an iron ship clean, whilst it causes an action which eats away the plates and rivets, and although insulation may have been made perfect whilst in dock or on the slip, still this state it is utterly impossible to maintain whilst the ship remains in use. The very water itself in which the ship floats becomes a conductor between the metals, and although paints may be employed to maintain insulation and prevent galvanic action, yet any spot from which the paint may be rubbed off and the water can reach, immediately becomes a starting-point or nucleus for the evil, and it is equally certain that the loss and destruction of the ship become merely a question of time.

Though the most rudimentary works on chemistry point out that the contact of two metals when immersed in a liquid sets up galvanic action, and results in the destruction of the weaker metal; and although scientific men of the highest eminence, both in their published works and lectures in this country and abroad, have shown this to be the case, nay, have even pointed out the fact that two pieces of a similar metal cut from one bar will, when brought into contact and immersed in fluid, develop galvanic currents, it is nevertheless a fact that many men professing to be scientific and learned in these matters, have actually decided that this is not the case, and in consequence set their wits to work to devise a mode by which copper or yellow metal may be attached to iron hulls; and one "engineer" actually proposed to attach one to the other, with no insulating material whatever between them. It is not a little surprising, when the results of attempts in this direction are analysed, to find the amount of quackery which in some cases is tolerated and in others encouraged, and the *ipse dixit* of such individuals at once accepted as conclusive, because, although practice shows they do not, theory says they *ought* to know all about it.

Galvanism is the term applied to express a peculiar form of electric agency, developed under particular circumstances, and productive of certain effects upon bodies which do not usually result from the ordinary modes in which excitation is practised;

in fact, it may be termed chemical electricity, as against the mechanical, magneto, or frictional system.

The process usually adopted in order to obtain galvanic electricity is to expose two plates, or portions of different kinds of metals, to the action of a fluid capable of exerting some kind of chemical action on one of the plates or metals, whilst at the same time it does not affect, at least in a similar manner, the other plate or metal, and then establishing a communication between the metals either by their direct contact with each other, or by the intervention of some conducting medium.

The result of this is, that a quantity of electricity is set in motion, with a continuous action so long as the conditions above described remain in force, and produce changes in the composition of bodies which can be accomplished by no other means.

It is now a well-established fact that galvanic action can be established between two pieces of a *similar* metal; and Captain Selwyn and others have found that two pieces of iron cut from the same plate or bar produced so strong a current as to "deflect the galvanometer to 90°."

He also related that he could "take one part out of a plate strongly negative, and another part strongly positive, a current passing which is capable of producing an enormous effect."

Mr. Rae, iron shipbuilder, remarked from his experience, "that in taking two pieces of iron from the same plate, and putting them into the same water, I have shown a current existing between them."

Captain Selwyn remarked, at the Institution of Naval Architects in 1864, "I have shown before another institution that there are no two pieces of iron, not even if they are cut from the same bar, or any two woods, between which galvanic action does not or cannot take place; and though the intensity of action in a ship be small, the surface operated on is so large as to be capable of producing most insidious and dangerous effects."

It was observed when the "Shannon," Captain Broke's ship in the celebrated action with the "Chesapeake," was examined, that the *oak* trenails had destroyed the *fir* planking for two or three inches round the trenail holes.

In 1821 Robert Dickinson patented improvements in the construction of metal ships, and, when the same are constructed wholly of iron, a means of covering them with copper, by the intervention of a non-conducting plank covering between the iron and the copper.

For applying this copper sheathing, thin planking was to be wrought all over the surface of the bottom, and attached to it either by screws from the inside, or by short bolts with their heads set deeply into the wood, and secured inside by nuts. The copper sheathing was then to be applied in the ordinary manner.

In 1841 Mr. R. Mallet patented coating iron with an alloy of zinc, *mercury*, and potassium or sodium, to prevent corrosion, and then covering the whole with some *poisonous* paint!

In 1852 Mr. A. Wall patented the application of mercury, or solutions of the same, to the hulls of iron ships.

The use of mercury or quicksilver as an anti-fouling, *anti-corrosive!* compound, has been again patented since, and some considerable attention directed towards it; but here again is a more dangerous material in exciting galvanic action than copper, proposed to be placed in contact with the inferior metal, iron, out of which the hull of the ship is composed!

Mr. Bakewell, in his 'Manual of Electricity,' places mercury *fourth* on the list, copper being fifth, and iron eighth; consequently, a few moments' reflection, or a proper knowledge of the subject and the causes of chemical action, would not have suggested the application of a more powerful material than copper (the injurious effects of copper being known from experience) to the iron of a ship's hull.

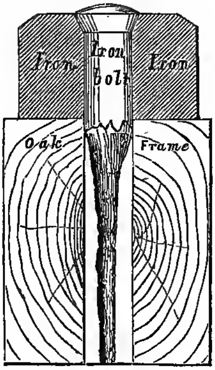
In a letter to the 'Standard,' which appeared in that Journal of the 7th January, 1867, Mr. F. N. Gisborne, the patentee of a mercurial paint or ointment, stated "that the anti-corrosive and anti-fouling paints (as patented by myself) effectually prevent the hull from fouling, and the iron from corrosion," and in the concluding part of the same letter he says, "when applied in its pure state and without adulteration, I do not hesitate to say that I will guarantee it to protect the bottoms of iron vessels from fouling, and the iron from corrosion."

The results of the trial of this and several other plans on the "Valiant" iron-clad during a period of eighteen months, as described at pages 71 to 73, in the report of the 'Standard' correspondent, who saw the ship in dock, and also from the correspondent of the 'Times' of Jan. 11th, 1867, are the best answers to this.

Copper, in whatever way it may be applied, is *certain* to injure the iron hull of the ship; and no matter how scientifically and carefully insulation may be carried out whilst the ship is in dock or on the ground, it is utterly impossible that the combination of circumstances to which such a ship is exposed when employed, can enable this state of insulation to be maintained for even a single day. It is an inexorable and certain law of nature that salt water, iron, and copper, shall set up galvanic action, the infallible result being the destruction of the iron; and though it is not near so powerful and rapidly destructive an action as would be obtained by the use of sulphuric acid, in place of the salt water, yet it is not the less certain nor the less fatal in its results.

The wood sheathing, by the absorption of the moisture from the surrounding water, becomes at once a conductor for the galvanic power from the iron to the copper, or *vice versâ*, and however carefully it may have been insulated at first, the straining and working of the ship, the blows of the sea, the friction or bumping of barges, boats, or against wharves, or piers, &c., the wash of the water over the copper sheathing and iron hull, the contact of the iron cable, nay, even the contact of a wetted rope, or the head of a single bolt, will each and all of them quickly and surely destroy this insulation, and set up or permit this destructive and fatal action; in fact, it may be safely said that maintaining insulation in practice under these circumstances is an utter impossibility, and attempts to perpetuate such a serious evil should be at once discountenanced and prohibited. The action of oak-wood in a timber ship on iron bolts is shown in fig. 2, and there is reason to believe that wherever iron is used in fastening together the portions of a wooden vessel used in *salt* water, that similar results take place.

FIG. 2.



It is well known that a wetted string makes a far better conductor for electricity than whilst it remains dry; and that when Franklin was using a kite for obtaining the electric fluid from the clouds, as the rain wetted the string so the fluid passed more freely than it did when dry. There can be no doubt that the water in the wood sheathing, or other material on which the copper of an iron ship is attached, and which is in contact with the iron hull and the copper sheathing, acts in a similar manner to the wetted string of the kite. At any rate, however it may occur, we have still the fact that the copper sheathing *does act* injuriously on the iron hull in spite of the absence of actual metallic contact, giving thereby abundant proof of the serious results which do not fail to attend the employment of these two metals when immersed together in sea-water.

The author has found, when using a galvanic battery to the ends of the wires of which balls of sponge were attached, that the shocks were given with much greater power when the sponges were wetted than when they were dry, which seems to prove that the water acts as a conductor of the fluid.

It is also well known, in the case of the telegraph wires, that when the damp is condensed on the inside of the insulator, and is in contact with the wire, that the fluid uses this dampness or wet surface as a bridge or path to escape from the wires, and so pass off to the ground.

The rules of Lloyd's Committee allow *iron*-fastened ships to be classed in the same manner as copper-fastened ships, "*so long as they remain unsheathed with copper*," and provided that they are *in all other respects* constructed in accordance with the rules.

Mr. Bakewell, in his "Manual of Electricity," published in 1859, gives the metals that excite electricity by their mutual action, ranged in the following order, those placed first acting in reference to those beneath as copper does to zinc:

1. Platinum.
2. Gold.
3. Silver.
4. Mercury.
5. Copper.
6. Lead.
7. Tin.
8. Iron.
9. Zinc.

Any two of the foregoing series will constitute what is termed a voltaic current. Thus, zinc will excite voltaic action in combination with iron; iron will take the place of zinc when combined with tin; and tin will take the place of iron when combined with lead or copper. The energies of these combinations increase as the metals are more distant from each other in the scale. Thus, the most powerful practical combination is that of zinc and platinum, the former being the most corrodible, and the latter the least corrodible of the ordinary metals.

M. Radermacher observed, at the Institution of Naval Architects, in 1866—"I believe that iron and copper are two dangerous elements to have together in sea-water, and I believe that to produce galvanic action does not need contact of two metals; but I believe that even wood saturated with salt water will form a great conductor, and produce galvanic action."

Mr. Murray remarked, at the Institution of Naval Architects, in 1867, that the "salts of copper," which are used in some of the "anti-fouling" compositions, do "not prevent fouling; the copper salts decompose in sea-water, they injure the iron by galvanic action, and do not keep clean more than four or six months." These he gave as the results which have been observed by him during many years at the port of Southampton.

The action of other metals on iron seems, as a whole, to be but little thought of, though their results often come under notice. For instance, the fixing to the stone of iron railings with lead is still followed, though most people must have seen its ill effects; and all railings which have been so fastened for some time will be found to be greatly damaged, or else almost eaten away just where the lead touches them.

Even steel and cast iron will exercise a similar action on wrought iron, that of the cast iron being more powerful; and it seems that the wrought iron is generally electro-positive with these other metals, and the result is, that it suffers in proportion.

Sir Humphry Davy ascertained that when two metals in contact are immersed in a saline solution, an increased action takes place on one of the metals, whilst the action of the solution on the other is diminished. Copper, for example, undergoes corrosion in sea-water; but when zinc is in contact with it, the corrosion of the copper ceases, and the destructive action is centred on the zinc.

The "protectors" devised by Sir Humphry Davy for preventing the loss of copper sheathing by exfoliation, consisted of a mixture of iron and zinc, which were attached in oblong slabs rounded off at the edges to different parts of the bottom over the copper sheathing; and the result was, that the exfoliation of the copper was most effectually prevented, and the galvanic action transferred to the "protectors," which became *quite soft,* and the metals, iron and zinc, were *quickly destroyed,* the copper meanwhile becoming dreadfully foul.

It is stated in the 'Mechanics' Magazine' for 1824 that "in a recent trial made on boats, it was found that the copper on their bottoms, which had protecting iron attached to it, became covered with animalculæ, which adhered so strongly to the copper that they could not be removed even by a broom."

Professor Faraday has remarked—"The association of iron also with other substances, if metallic, will much affect it; thus a wharf of cast iron might occasionally be greatly injured by making fast to it vessels that are coppered, using iron cables."

Dr. Medlock, F.C.S., gives his opinion that "copper in any shape whatever, whether in the form of oxide or of salts of that metal, would exert a powerful corrosive action on the iron with which it came in contact; the copper salt would be reduced to a metallic state, and for every equivalent of copper reduced a corresponding equivalent of iron would be oxidized and destroyed. Although the action might not be immediately perceptible so long as the coating remained sound, yet I believe that the mischief would be constantly and silently going on, and be discovered only when the iron is seriously injured. I would therefore advise you not even to *think* of using copper in any shape as a paint for iron ships."

Dr. H. M. Noad, F.R.S., speaks of having "arrived at the conclusion that no compound containing copper can long resist the action of sea-water, and that in whatever form that metal may be contained in a pigment, it would eventually take the form of oxichloride, which salt would undergo such a decomposition as to lead to the deposition of metallic copper in a thin porous state upon the exposed portions of iron, particularly on the rivets, and that, under such circumstances, a rapid corrosion of the iron must take place. Copper in any form ought not to enter into the composition of any substance having the object of protecting the bottoms of iron ships."

Dr. Normandy, F.C.S., speaking of the decomposition of salts of copper in contact with iron, remarks that copper paint is not at all "suited to the painting of iron ships."

Mr. Scott Russell remarked at the Institution of Naval Architects, in 1862, respecting the employment of copper on the submerged portions of iron ships, "There will be chemical action of some kind unless very serious precautions are taken."

Captain J. R. Engledue, who was formerly connected with the steamers of the Peninsular and Oriental Company at the port of Southampton, states that "I have at various times tried preparations of copper on iron ships, and in *every case* found the iron and rivets damaged."

Mr. Lamport said, at a meeting of the Institution of Naval Architects, "If iron and copper be combined in an acid or sea-water, iron, being more electro-positive than copper, is chemically decomposed, or, to use a more common phrase, is 'corroded.' The galvanic current passing from the iron or generating metal to the copper as the receiving metal changes the condition of the latter from a naturally electro-positive condition to one relatively negative. The metal thus rendered electro-negative by the galvanic current becomes proof against the action of the fluid as a chemical agent. No decomposition takes place, and it assumes the condition of a 'protected' metal, while the more positive one is still more rapidly eaten into and decomposed by the stimulated chemical action. If, in place of copper and iron, we take iron and zinc, the same process takes place, *reversed*, however, as regards the iron. Zinc, being more positive, is chemically disposed, and the current passing to the iron renders it negative, and consequently insoluble or 'protected.'"

When copper sheathing was first applied to iron-fastened ships, it was soon found that the iron bolts became rapidly oxidized from the action of the copper; and although many plans were tried to obtain insulation, no success attended these efforts, and in consequence mixed or yellow metal, or copper bolts and fastenings, had to be employed in vessels which were to be sheathed with copper or yellow metal.

The 'Western Times' in April, 1864, remarks, "We have great complaints from nautical men of the destructive action of some of the copper compounds used on the bottoms of our iron-sides. The subject is of the utmost importance."

The numerous instances quoted in this work of the destructive action of copper on iron hulls will prove that these complaints are not without reason; and it is greatly to be regretted that although chemical laws show how fatal and *certain* this action is, that people should obstinately persevere in trying to set these laws at nought, and that they should be allowed to prove the futility of their efforts by jeopardising the safety of our splendid iron-clads.

It is said that the Spanish Admiralty tested various plans and preparations of copper for three years, and having satisfied themselves of their injurious effects, and found that it was perfectly impossible to prevent abrasion and galvanic action, entirely excluded them from their arsenals. If this be a fact, it speaks well for the intelligence of those in power, and it is to be regretted that others have not profited by their experience.

Captain Selwyn has well remarked that "it would be cheaper to *build* our ships of *copper*, than to go into plans for making *copper bottoms* to *iron ships*."

"The protection of an iron bottom," says the 'Engineer,' "offers a double difficulty. It has not merely to be preserved from the sea-weeds and barnacles, but also from *bodily corrosion*. A copper bottom would indeed preserve the iron vessel from sea-weed, but not from corrosion; *this it would indeed enormously intensify*."

The 'Standard' of July 11th, 1865, speaking of iron ships, well remarks: "Upon those bottoms you cannot place copper without the intervention of plank, and even then you cannot be for a moment sure that the galvanic action of copper on iron has been completely neutralised. Thus, copper, apart from the costliness of the application, must as a matter of prudence be discarded from iron bottoms. Then, if you adopt the coating of iron bottoms with brass or glass, the brass or glass becoming incorporated with the iron and presenting an imperishable surface to the water you supersede the principle of exfoliation, the principle of the wasting, and from sheer necessity secure the absence of corrosion at the cost of inviting all the vegetable and animal life of high latitudes to take possession of your iron bottom. Why copper or yellow metal on a wood bottom keeps clean is not because vegetable and animal life decline to touch them, but because the waste or exfoliation of the yellow metal on the copper speedily gets rid of them. So the getting rid of exfoliation or waste is practically the getting rid of the possibility of keeping bottoms clean at all. The correct view to take on the whole is, that as exfoliation or waste is the condition of keeping bottoms clean, and as copper cannot be attached to iron without a greater risk than that sought to be evaded through its application, an exfoliating or wasting composition must be accepted as a necessity and not a choice."

It is most remarkable that the destructive action of copper on iron, either in contact with or proximity to it in salt water, is so little understood or admitted, and more unaccountable that where it is well known its advocacy should be persisted in by those who should, and in some cases do, certainly know better. One weekly so-called engineering paper, the 'Mechanic's Magazine,' at one time writes thus:—"No means of attaching copper sheathing to an iron ship, however ingenious, can be relied on to preserve perfect insulation between the two metals under the ordinary conditions to which a ship is exposed. A chance rub or a blow may at any time convert a coppered iron ship into a huge galvanic battery, in which the iron, the very body of the ship, is being destroyed." Further on it states that the only metal that can be used with safety for sheathing iron ships is zinc, it being the only one "which it is practicable to use," because the zinc is "electro-positive" to the iron, and "there is no reason to doubt its success."

At a later period we find this same journal writing as follows :—"As to finding a substance whereto marine plants and animals cannot adhere, we need not go far; that has been known to us, and used by us these many years, viz., copper, or an alloy of copper, and, as far as we know, there is *no other substance that is efficient.* There is a widespread error existing in the minds of almost all those who have turned their attention to this matter; it exists where we should think it ought not. It is thought that wherever two dissimilar metals touch, there must be voltaic action set up. This can only arise from want of experience in such matters. They apparently do not know that three conditions are necessary to the existence of voltaic action, viz., two dissimilar metals, and at least moisture, speaking with reference to the sheathing of ships, for other substances may take the place of metals."

It is enough to provoke a smile, if it did not give rise to other feelings, to look over the recorded attempts of various persons to employ copper or yellow metal on the bottoms of iron ships, without at the same time encountering the silent and dangerous results of galvanic corrosion. Each party *professes* to avoid galvanic action, and talks loudly of the "perfect insulation" attained by his peculiar method; but even admitting for a moment that each of them had attained the most perfect insulation possible, they each and all forget that this is destroyed the moment the ship gets afloat by the fact that the water in which the ship floats, from acting as a conductor, is the best and most convenient means of instantly destroying it.

In a discussion at the Institution of Naval Architects in 1864, Mr. Lamport said, "Mr. Grantham makes light of the fact of chemical action; but any gentleman who has had his money invested in a ship in which iron is contiguous to copper, will corroborate what I state, that even iron bolts, covered as they are over the heads, are generally eaten away, and how? Simply by the washing of the water up the sides causing a galvanic action between the two metals, and thus producing the chemical action which leads to so deleterious an effect. Silently and persistently the mischief may be working, until its full effect be manifested, but perhaps never acknowledged in the total loss of the ship at sea."

Mr. Grantham stated that in a composite ship built with iron frames, wood-planked, and coppered, the result was just what we should have supposed—the frames and plates in the inside of the ship forming the stringers were found to be free from corrosion, *but the bolts were found to have perished, or were beginning to perish, in consequence of their approximation to the copper.*"

Various as are the modes which have been proposed and adopted for obtaining insulation of the copper or yellow metal used in sheathing iron ships, in no case have any of the projectors alluded to the fact that the water, washing over the unsheathed portion of the iron hull, and being in connection or contact with the copper or yellow metal, at once destroys this insulation; and that from this very fact being unknown, or at least unnoticed, the greatest and most serious dangers arise. A ship sheathed with copper or yellow metal, and assumed to be perfectly safe from galvanic corrosion because of the perfection of the insulation, or means employed to produce it between the hull and the sheathing, may be kept at sea or in use whilst this destructive action proceeds with fatal rapidity and silence; and the fact that no security has been or can be obtained from any presumed insulation may be only found out when it has proceeded too far to be checked, by the sudden failure of the hull, or by its leaky state.

Several persons, so persistent in the belief that nothing but copper or yellow metal will do for sheathing, and at the same time admitting that copper or yellow metal produce serious effects when in contact with iron in sea-water, have actually proposed "lining" or covering one side of each sheet of the above metals with tin, pewter, or some other combination; and then when the "tinned" or "pewtered" side is applied next the hull of an iron ship, "no injury through galvanic action could arise."

It has been said that "some use a layer of wood between the iron and the zinc plates with their fastenings; whilst others use felt in lieu of wood for the same purpose. Amalgamated zinc plates are another variety of the same general principles, while several inventors propose to cover or encase each iron plate with a thick coating of other metals, such as copper or brass, by galvanic action, the metals being precipitated upon the iron to any thickness required!"

M. Roux, in his first attempt at preserving iron hulls and preventing fouling, used a chemical composition or paint which could be easily applied to a ship's bottom, but he soon found that a composition would not stand the friction of anchors, cables, ropes, and small boats; and to prevent the growth of vegetation he tried mixing the salts of copper with the composition, or else throwing copper filings on it whilst wet or fresh laid on. The result of all this trouble, however, was that galvanic action was soon set up, and all his care and trouble went for nothing.

Mr. Lamport, at the Institution of Naval Architects, in 1864, said—"Chemical action forbids the contact of copper or yellow metal sheathing with iron."

Captain Selwyn remarked, at the Royal United Service Institution, in 1864, that "with iron ships copper is out of the question; there is no possibility short of casing the entire ship by the galvanoplastic process of preventing the excitation of a galvanic current and the consequent rapid decay of the iron, which is the inferior material in this galvanic couple. Even if the metals could be separated the cold water would act as a conductor, and we have to deal here with enormous quantity, though low tension; therefore copper, or any other sheathing which is of metal or includes metallic compounds higher or lower in the galvanic scale than iron, is inadmissible."

The 'Steam Shipping Journal,' of October 30th, 1863, after having given numerous instances of the fatal damage caused by combining copper or yellow metals and iron in the hull of a ship, and then exposing them to the influence of sea water, says—"These demonstrated facts on so grand a scale will destroy many theories, and are valuable to the shipping interest as a monitor, when projectors are advising outside planking and copper sheathing under water to iron hulls."

The same paper further remarks, in reference to the employment of this principle by shipowners, and the serious results which would inevitably follow, that such vessels "would fall to pieces in about a year, supposing the galvanic process of decomposition were to keep pace with the destruction actually proved to have taken place in the four and a half inch plates of the "Royal Oak," and nothing done to protect the upper part of the hull from this insidious enemy."

It has been frequently urged that the copper or yellow metal, when used as a sheathing for iron ships, will not produce any injurious effects if carried above the load water-line; but, as the 'Steam Shipping Journal' has well observed, "All vessels roll at sea, and heel over under canvas, therefore there must be a point where contact takes place and galvanic action is generated. Our ship-builders have to overcome this difficulty before sheathing iron hulls with copper can be safely and economically applied."

Supposing, however, that the most perfect insulation can be obtained at the commencement, it will, if preserved, almost amounting in practice to an impossibility, have the desired effect; but suppose a ship so sheathed touches the ground, or an anchor on a foreign station, or on her *outward* voyage to a port where she cannot be docked for examination, although not necessarily leaky; or suppose she crumples up a sheet or part of a sheet of copper on her fore-foot or bows by the friction of her cable, or any part of her hull, so as to allow a mere film of sea-water to touch the iron skin, her destruction in a few months would be inevitable, seeing that the plates of the "Royal Oak" were eaten in to a depth of *five eighths of an inch in five months!*

An experiment for obtaining insulation was tried with a piece of iron 6½″ long, 3″ wide, and ⅝″ thick, which was carried out in the following manner:—Twelve holes each ¼″ di. × ⅜″ deep, and 1⅜″ apart, were drilled on one side of this piece of iron, and into each of these holes ebonite plugs or bushes were driven so that they might form holding places for the nails, and prevent metallic contact. On the face of the iron, and covering all the holes and plugs, was placed a piece of stout tarred felt, over this a piece of vulcanized india-rubber, and on this a piece of Muntz's yellow metal, in which were holes corresponding to those in the iron, and short nails of the same metal were then driven through these holes into the ebonite plugs, each punching out a small disc of the rubber and felt, and driving them down to the bottom of the hole. By this plan the water was prevented from getting between the felt and the iron, and it was thought that perfect insulation was most certainly obtained, and all risk of corrosion from galvanic action prevented.

This piece of iron thus prepared was sunk in the sea by order of the Committee of the Royal Commission on Iron Plates, and left there for twenty-eight weeks, or a little over six months, at the end of which period it was taken out and the following results were obtained:—"On turning back the yellow metal, rubber, and felt, at one end, and drawing out some of the nails, it was found that no water had obtained ingress between the felt and the iron, consequently the iron was quite dry and presented its natural appearance, no rust or corrosion being apparent. On the under side of the iron, which was not coated with the felt, and on which no yellow metal was placed, as well as the edges of the iron all round, corrosion had begun, and on the edges it presented the fibrous appearance of the metal usual in such cases, whilst on the under side it had begun to form holes, and the plate was considerably eaten. This piece of iron in its state as taken out can be seen at the offices of the author.

From this it would appear that, no matter how carefully insulation may be made between the hull of the ship and the copper or yellow metal sheathing, nor how soundly this insulation may be maintained when at sea, still the water being in contact with the copper or yellow metal sheathing and the iron of the hull also, would be quite sufficient to cause corrosion; and it is totally impossible in the case of a ship at sea to prevent the water forming a connection between these two different metals, and causing this most insidious, dangerous, and fatal action.

The certain results of this course cannot be denied, and it is greatly to be regretted that it should be carried out on so extended a scale as it has been, and still be viewed with favour in those quarters where its adoption is most likely to be countenanced and its evils perpetuated. The cost of frequently stripping our large iron-clads, in order to see how this action goes on, will be very great, and the loss of time involved thereby will amount to something very considerable; but the worst of it is that all will be going on in spite of everything that can be done to prevent it. No precautions that can be taken with an iron-clad sheathed with copper or yellow metal whilst at sea *can* prevent this, or even *limit* its sphere of action; and until we can set at nought the inexorable laws of nature this result will always follow.

It may be taken as a sure thing, that when the copper or yellow metal sheathing on an iron ship fouls when at sea, the galvanic action generated by the presence of the two metals in sea-water is attacking the iron of the hull; for if it expended itself in causing the copper to exfoliate, no fouling would remain on it. Sir Humphry Davy found precisely this result when he placed his iron protectors on the men-of-war, and from a precisely similar reason, viz., that the copper was preserved at the expense of the iron; and when these protectors were taken off, the copper again exfoliated, and the fouling was removed.

Captain Selwyn has stated "that wherever you put copper and iron together in a vessel exposed, not alone to the water of the sea, but even to the moisture of the atmosphere, there you will inevitably have a strong galvanic action. *There is no known means of stopping that.*" Speaking of the idea of obtaining insulation, or the prevention of galvanic action by placing a skin of wood between the iron hull and the copper or yellow metal, he observes—"There is no part at which there is not a deposit of salt water upon it, and that salt water is the conductor to continue the galvanic action through."

The certainty with which galvanic action can be set up is not so remarkable as the *very small amount of materials required to generate it,* the action *not* being dependent upon the *quantity* of surface exposed to the water. For quantity and energy of action a large surface is required to be exposed; but galvanic action is not more surely generated thereby, nor does it differ in its results, *except in intensity, whether it be one square inch or one square yard* that is exposed.

In this fact lies the great danger, for persons are too apt to assume that because there does not seem any very striking appearance of the conditions required to form a galvanic battery being in existence, that *therefore* no importance need be attached to it, and consequently the evil is suffered to exist and make sure and silent progress towards those very results they are so anxious to prevent, and might have done, had they given proper consideration and attention to the subject; and it is only by some fortunate chance that evil results can be prevented.

Mr. Bakewell states, in his 'Manual of Electricity,' that "two wires, one of platinum and one of zinc, each one eighteenth of an inch in diameter, placed five sixteenths of an inch apart, and immersed to the depth of five eighths of an inch in acidulated water, consisting of one drop of oil of vitriol and four ounces of distilled water, and connected at the other extremity by a copper wire of eighteen feet long and one eighteenth of an inch in thickness, yield as much electricity in little more than three seconds of time as a Leyden battery charged by thirty turns of a very powerful electrical machine in full action. This quantity is sufficient, if passed at once through the head of a cat, to kill it."

It is stated in 'Experimental Researches' that "zinc and platinum wires one eighteenth of an inch in diameter, and about half an inch long, dipped into dilute sulphuric acid so weak that it is not sensibly sour to the tongue, or scarcely to our more delicate test-papers, will evolve more electricity in one twentieth of a minute than any man would willingly allow to pass through his body at once."

Dr. Wollaston found that a single plate of zinc, with a superficies of one square inch, when properly mounted and suspended in dilute sulphuric acid between two copper plates of similar dimensions, was more than sufficient to ignite a platinum wire of $\frac{1}{3000}$th part of an inch in diameter, which formed part of the connection between the two metals.

The 'Moniteur de la Flotte,' a French naval periodical, states that when the "Gloire" was taken into dock the following phenomenon, "which none on board the ship were aware of, showed itself," and this was, that "the copper sheathing, being brought too close to the under-water armour-plates, had set up galvanic action, which, acting like a voltaic pile, had *greatly corroded* the plates below the water-line."

In the 'Standard' of May 1st, 1862, it was stated that "Foreign Governments also now building iron ships of war and transports, are fully alive to the importance of protecting the plates and rivets of their future navy from premature destruction by using a composition paint containing no copper," and that some steamship owners and companies "have long since tried preparations of copper, and satisfied themselves of its destructive effects on iron whenever the under-coating accidentally and unavoidably becomes scratched up by chain cables, dock fenders, buoys, or floating wreck."

The 'Steam Shipping Chronicle' remarked that "it is the opinion of practical and scientific men that *any* preparation containing copper *must* eventually prove injurious to the rivets and plates of iron ships, whilst its efficiency in keeping off shelly incrustation longer than any other composition is *by experiment* found to be a fallacy."

The 'Shipping and Mercantile Gazette' of the 5th December, 1862, stated that the "French floating battery 'La Gloire' has lately been examined, and found to be seriously injured by the action of copper on her iron plates, the whole of which below the water-line will have to be removed, being converted into a kind of plumbago by galvanic action. We had occasion, some time since, to call attention to the extraordinary state of Her Majesty's ships "Triton" and "Sharpshooter." On their being docked for examination, the iron plates were in some places reduced to the thickness of writing paper, and in the case of the "Triton," the scrapers actually *went through the plates* when removing the tons of oysters, barnacles, &c., attached to her bottom. It appears that this ship had been coated with a *preparation of copper*, and the destruction of the plates and rivets arose from *galvanic action* on the exposed surface of the iron where the under coating had become rubbed off under the bows and forefoot, and along the light load water-line. The salvation of this ship from foundering was no doubt occasioned by the adhesion of the shell-fish."

In the 'Standard' of October 27th, 1863, it was stated that the "Royal Oak," of iron sheathed with wood and coppered, when the water was emptied from the dock in which she was placed, discovered "a most remarkable appearance, which created no small consternation among the authorities. The armour plates adjoining and in contact with the copper sheathing were found to be eaten away by galvanic action, presenting a series of corroded holes running into each other, from half an inch to five eighths of an inch deep. Some of the plates contained *no less than* 188 *of these, whilst none had less than* 40. Several detached holes are of an oval form, as though gouged out with a steel tool of all sizes, from that of the bowl of a salt spoon to that of a gravy spoon, and of equal depth; and some of the heads of the bolts had become recessed to the depth, size, and appearance of the bowl of a small ladle. Numbers of the holes had run into one another to the extent of five or six feet, five eighths of an inch deep and upwards, altogether presenting one of the most remarkable appearances ever witnessed. This ship has only been about *eight months* in the water! These holes and corrosion appear to have occurred wherever the red lead or under coating had been rubbed or washed off."

The 'Times' of October 28th, 1863, in remarking on this, said, "Wherever the least abrasion or friction has taken place, and the red lead or composition has been rubbed off from the surface of the plates, galvanic action has been in full force. This is remark-ably evident in one part—the hook, several feet long, which keeps the accommodation ladder in its place, is fastened to the ship's side by an eyebolt; when not in use the end drops below the level of the sea between plates 11 and 12, it has been allowed to sway about fore and aft, and has thus worked off the composition, and the action of the copper has in consequence had full effect here; a portion of a circular groove exists in each iron plate, each portion being two feet six inches long in the sweep, and about three eighths of an inch in depth. In some places, just at the junction of the iron with the sheathing, the edges of the iron plates are corroded for lengths of six inches to a foot, and in one place under the quarter this kind of corrosion extends to a length of ten feet."

As an instance of the results of the application of copper *in any form,* when applied to an iron ship, may be cited the "Triton," which had been coated over with a preparation of copper, and when taken into dock at Keyham it is said that "by the galvanic action where the bitumen had gone off in flakes, the plates were in some places reduced to the thickness of writing paper, the scrapers and slices used for detaching the oysters, &c., going right through the plates."

The 'Times' of November 17th, 1859, in referring to the results on a ship which had been coated with a preparation of copper, says, "The result is considered as having incontestably proved that preparations of copper are of little value in preventing incrustation or fouling on the bottoms of iron ships, while their galvanic action must sooner or later prove injurious to the rivets and plates."

The "Black Prince," in 1863, was coated on one side with the copper solution of Mr. Hay, the Admiralty chemist, at Portsmouth, and the other with the copper composition of Mr. McInnes. *Five months after* she was taken into dock at Devonport, when the following very important results were obtained:—

"Both sides were *much corroded,* but the oxide of copper of Mr. Hay seemed to have been less efficacious than the sulphate of Mr. McInnes. The sulphate of copper was the cleanest, there being less weed and barnacles on it; whereas on the side done with the oxide of copper, thousands of small mussels were found adhering under the lands of the plates, and the plates themselves, on the flat of the bottom, were covered with coralline worm shells very thickly incrusted."

It is a curious fact, and no less curious than true, that in spite of all the experience gained of the ill effects of copper, *however applied,* on the hulls of our iron ships, its use should be still persisted in, and the serious evils and dangers which accompany it set at nought; but still such is the fact, for the author finds that the 'Times' of November 30th, 1864, announced that "Admiralty orders" had been given for the "Prince Consort," iron-clad, to be coated with "copper and felt sheathing on Commander Warren's plan, for trial"! The "Northumberland" also will be coppered.

It has been said that the reason why copper and yellow metal are in such favour with the Admiralty as materials fit and proper to be used for sheathing iron ships, is because there is a large quantity in store at the dockyards, and therefore it ought to be used!

Fouling, although a most annoying, expensive, and troublesome evil, is not so serious and fatal a drawback as corrosion. This latter involves the destruction and loss of the ship, whilst, if not allowed to proceed so far, still it produces a diminution of the strength of the hull, and renders the ship less sea-worthy and safe, the results of its action being sure, silent, and hidden. An hidden enemy is the most difficult to guard against, and the least able to be attacked, and it is only by finding out what it is that causes the corroding action in the hull, and using all and every means which has been devised and science points out as being able to counteract it, that any hope can be had of obtaining immunity from its fatal and certain ravages.

The exfoliation of the surface being the action which keeps the metal sheathing clean when placed on the hull of a wooden ship, it must therefore be evident that what is required as a sheathing for iron ships is a metal that is positive to iron, or will absorb the galvanic action caused by the water and different metals being in contact, and will therefore preserve the iron, which will exfoliate or peel off sufficiently to remain perfectly clean whilst the ship is afloat, in whatever climate she may be; and be at the same time capable of wearing some three to five years, without requiring renewal.

Of all the metals known, and obtainable at a reasonable rate and in sufficient quantity, zinc is the *only one* which, when in metallic contact with iron, fulfils these conditions; and for these and many other reasons it stands pre-eminent as a preserver of iron both from corrosion and fouling. The purity of the zinc, however, has an important influence on its satisfactory performance, and also on its successful application; and for this reason it becomes very desirable that care and judgment be used in its selection, and careful tests be employed, to decide its applicability to this purpose.

The protection afforded by the zinc to the iron is so perfect that in all experiments the smallest "fay" or feather edge left from the shears on the iron has remained in its original form, even after twelve months' immersion in sea-water; and it would seem to show that, with ordinary care, there is no reason why the skin of iron ships protected by zinc sheathing should not be indefinitely preserved.

The advantages and importance in a national point of view of having obtained a mode by which the bottoms of iron ships can be kept as clean and free from fouling as a wooden ship sheathed with copper or yellow metal, whilst at the same time the iron composing the hull of the ship is preserved from corrosion or deterioration, cannot be sufficiently estimated or too highly valued; and it is hoped that immediate steps will be taken to construct an iron ship on this mode, so as to give a proper opportunity for realising its benefits and advantages, as the enormous saving which will accrue therefrom to the nation and the shipowner cannot be questioned.

Captain C. P. Coles remarked, at the Institution of Naval Architects, in 1866—"The finest and strongest iron vessels, with iron bottoms, if sent unprotected to sea, would soon become useless and dangerous."

It is very difficult to obtain accurate and authentic accounts of the extent to which corrosion prevails amongst the ships of the navy, or the merchant service, any cases of the sort being generally kept very quiet, and remedied by removal of the plate or other means; but from time to time some of them get into the papers, are noticed by a passing glance, and then forgotten; it apparently being assumed that there is no remedy for it in existence, nor one to be devised, but that, like noise to motion, it is an inseparable accompaniment of the iron ship.

There can be no doubt that the constant and continued failures of the multitudinous "anti-corrosive" paints, putties, plasters, glues, powders, pickles, and other nostrums, which have been so persistently and loudly introduced to our notice, have done more to perpetuate this belief and divert attention from the proper and thorough investigation of the subject, than anything else; and as Captain Selwyn has well remarked, in 1864, at the Institution of Naval Architects—"When the chemist gives up the notion of poisoning the barnacles, and the idea of coppering iron, he will probably be able materially to aid the sailor in keeping his vessel's speed, when the naval architect has given it to her."

# CHAPTER VII.

## IMPROVED CONSTRUCTION.

In this chapter the author has endeavoured to give a plain and practical description of Mr. Daft's plan of construction and sheathing of iron ships, and to examine it in all its bearings, with the view of finding whether there existed any serious defects in its principle, or any practical difficulty in carrying it out. It is hoped that the results of his investigations will satisfy those most interested in the subject; and it seems to the author that nothing but ignorance or prejudice can operate as a drawback to its most extended adoption.

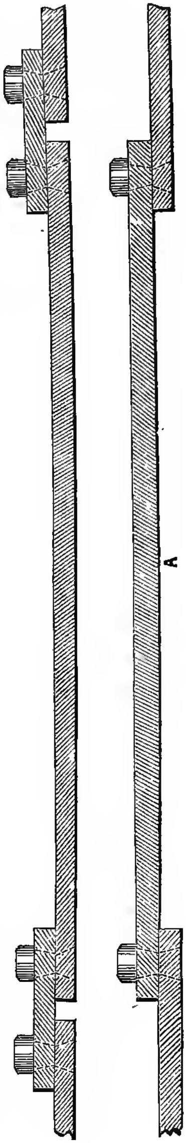
Up to the year 1863, the most general plan of constructing iron ships was that known as the "in-and-out" strake system, formed by placing one or every other strake *upon* the frames or ribs of the ship, and the next or every other strake *outside* these, the lap or junction of the edges being riveted, the result being a narrow trough or space and a wide plate or strake in alternate widths, and, when viewed endways, giving the appearance shown at A in fig. 3. By this plan the ends of each plate in each strake formed a "butt" joint, the laps being attainable only on the longitudinal seams; and these butts form always the weakest and most troublesome parts of the ship.

In the year just named, Mr. Thomas B. Daft, C.E., patented his system of constructing and sheathing of iron ships and vessels, by means of which many great and important advantages, hitherto unattainable, are easily and readily secured; and there can be no doubt that this system must be extensively adopted as its advantages become known and appreciated.

The frontispiece shows the mode of construction and sheathing patented by Mr. Daft; and it will be seen that *each* strake of plating comes *on* the frames, instead of every other strake, as is the case with the "in-and-out" strake system; thus doing away with the liners and long rivets through plate, liner, and frame, which are known to be objectionable, whilst both end and longitudinal seams can be double or single riveted, as may be preferred. The section, full size, shows the skin, teak, nail, and sheathing.

If it is preferred, the butt straps may be used in long lengths as stringers, placed on the frames, the plating coming against them, and the spaces filled in with liners, as shown at K, fig. 5; but this is not considered so good as when the plates are placed *directly on the frames*, because this mode involves the use of long rivets, which, as before stated, are objectionable on account of the difficulty of making a good job in closing them.

Fig. 3.



It is hardly to be expected that any new plan, however good, simple, efficacious, or meritorious it may be, should secure the support and approval of all parties; and accordingly, in this instance, numerous objections, none of which, however, can be sustained for a single moment, have been urged against it.

First, because this system abolishes the "butt" joint and substitutes a lap, parties are found to condemn it and prefer the "butt" joints, on which they "place great reliance." Next, because some strips of wood are introduced between the edges of the plates, to form a hold for the sheathing-nails, it is at once condemned, because they would work out, and, moreover, they weaken the structure. Next, because each plate becomes a "lap," and can be caulked all round, no "butts" being required, it is objected to, because the ship cannot be so strong as when "butts" are used, and, moreover, cannot be made so tight. Next, because the joints of the plates do not butt against each other, though the vessel may be as strong in tension, she is much weaker in compression.

It would be tedious to notice the frivolous objections which have been raised by some people; therefore it is proposed to confine attention to the most weighty, especially as without due consideration and a thorough comprehension of the principle they may at first sight appear to have some foundation.

Some persons, evidently without having duly considered it, object to this principle of construction, alleging that it cannot be so strong as the ordinary in-and-out lap and butt, because the straps or welts are rolled as *bars*, and not as *plates*, and from the strain being applied *across* the fibre, instead of *longitudinally with it*, it must therefore be all that the weaker. It will be interesting just to look into this view of the case, and see what grounds there are in support of it.

Dr. Fairbairn relates that the results of his experiments on Yorkshire, Derbyshire, Shropshire, and Staffordshire plates, when tested in the direction of the fibre, and also across it, gave the following mean :

| | PER SQ. INCH. |
|---|---|
| Mean breaking weight in direction of fibre . | 22·519 tons. |
| „ „ across the fibre . . | 23·037 „ |

Or a difference of strength of about $\frac{1}{46}$th, when tested across the fibre, in favour of applying strains in that direction. No description is given of the mode in which the plates were arranged for undergoing the tests, how the tests were applied, or what kind of apparatus was used; and it may be remarked that no other engineer seems to have obtained results of a similar character.

Mr. David Kirkaldy, whose almost innumerable and patient investigations of the strengths of all kinds of metals are so well known, tested 167 plates lengthwise of the grain or fibre, and 160 plates crosswise, and obtained the following results:

| | LBS. |
|---|---|
| Mean breaking weight in direction of fibre . . | 50·737 |
| „ „ across the fibre . . . | 46·171 |

He experimented with a great number of makes of iron in various forms, and he found a mean result of 9·8 per cent. in favour of the strain being applied *with* the fibre instead of *across* it.

Mr. Edwin Clark, in his experiments on iron for the Conway and Britannia Tubular Bridges, obtained the following results from his experimental tests of the plates:

| | | TONS. |
|---|---|---|
| Ultimate breaking weight in direction of fibre, | Exp. 1 | =19·66 |
| Exp. 2 . . . . . . . . | | =20·2 |
| „ „ across the fibre | Exp. 1 | =16·93 |
| Exp. 2 . . . . . . . . | | =16·7 |

From these results it would seem that there is a reasonable ground for the objection, that strains across the fibre are not so well resisted as when applied longitudinally, or in the direction of the fibre; and were it the fact that the straps could only be applied so as to receive the strain across the fibre, there can be no doubt that the objection of weaker construction would hold good.

It fortunately, however, happens that there is not the slightest difficulty in so arranging the manufacture of the straps, that when applied they shall receive the strain in the direction most favorable to utilising the strength of the material; and this is easily and readily accomplished by rolling them as plates, and cutting them so as to have the fibre in the direction required, whereby this objection is at once overcome, and the defect of construction, which the use of ordinary rolled bars for this purpose would appear to cause, is effectually removed.

This is quite in accordance with the directions of Lloyd's Committee, who state in their Rules for the Construction of Iron Ships, "that all butt straps, or lining pieces to butts, be fitted with the fibre of the iron in the same direction as the fibre of the plating to which they are riveted."

Mr. Grantham, in his work on 'Iron Shipbuilding,' has plainly shown the superiority of the "lap joint" over that of the "butt;" and it is well known that the "butt-joint" system, as applied to carvel-built ships, was so imperfect and objectionable as to lead to the almost universal adoption of the "lap," as exemplified in the plan of "in-and-out" strakes.

The "butt" could *never be made tight;* consequently the more "butts" there were in a ship, the worse she would be for tightness; for, do all that could be done, by no means could the "butt" be made either *strong* or *tight,* nor could *any amount* of fitting or caulking get over this difficulty.

The "lap," on the contrary, *can* be made tight by caulking, and this is urged as one of its greatest advantages. That this is so, must be evident to any one who is ever so slightly acquainted with the construction of iron ships; and it is in consequence of every plate being put *on* the frames, and forming a joint with *all* "lap," that the superiority of Mr. Daft's plan of construction is so great and manifest; and where this is not admitted it must be attributed to ignorance or prejudice, or a total want of comprehension of the principle.

Mr. Grantham, in his paper on "Jointing and Riveting Iron Ships," read before the Institution of Naval Architects in 1862, says, "As regards the butt joints, it is notorious that in no place do iron ships sooner show weakness than in these; and in no part of iron shipbuilding is the system so deficient. Supposing the two edges of the plate are made quite true, there is no certainty of their being brought and kept solidly in contact till the riveting is completed. The slightest motion will separate them, or the slightest projection will keep the joint open. All questions are set at rest by the caulking tool—a flat chisel, which is passed over the joint—knocking down the burr which has before been raised, and closing the plates at the upper part of the joint. This system makes the joint water-tight, but is so evidently defective in strength, that no one ought to be satisfied with it."

Dr. Fairbairn has well remarked that "A single defective joint may endanger the safety of a ship; how much greater, therefore, must be the danger if the principle throughout be unsound, and the whole of the joints of an imperfect character !"

An iron ship well built, on Mr. Daft's patent principle, becomes far stronger than it is possible to make a similar ship on the ordinary plan, besides being far tighter and safer in that respect, from having no leaky "butts," and because each and every plate being all "lap" can be caulked all round, and thus equal tightness throughout secured.

The author has been constantly met with the assertion, that the teak strips, which are put in in a dry and compressed state, and are further expanded by the sheathing nails which are driven into it, *must* work out, and could never be made to keep in. It will be desirable to investigate the feasibility of this remark.

Mr. John Grantham, in his paper on the "Strength of Iron Ships," read before the Institution of Naval Architects in 1860, when speaking of a *timber*-built ship, says, "Each bolt is a fixed point, the seams being in constant motion. Now, in an *iron* ship there is no such motion in the seams; the outer shell is as nearly as possible made into one plate." And he further says that "a movement in a lateral direction is impossible."

At the Royal United Service Institution, in 1862, he stated that, taking the *lateral* motion of the "Warrior," iron-built iron-clad, "to be four inches on her entire length, I make the average opening at the outer edge of each seam in the lengthways of the ship to be about $\frac{1}{17,000}$th part of an inch, or $\frac{1}{70}$th part of the thickness of an ordinary sheet of writing paper, and in the inner edge of the seam to be absolutely nothing but what may be allowed for in the positive direct stretching of the plate between each frame at every motion of the ship."

Were it possible for a ship to work so in a heavy sea that the teak could come out, it would be evident that this could only happen by the *rivets becoming loose*, in which case there can be very little doubt that all tightness would be lost, and the ship most probably go to the bottom. If built with common "laps" and "butts," and working to a similar degree, she would, as a matter of course, go to the bottom, "the water," as in the case of the unfortunate "London," "would go in everywhere," and a similar result speedily follow.

Dried compressed teak, driven tightly between the edges of the iron plates, swelled up by the moisture, and further expanded by the sheathing nails, is not like teak caulked into teak, but holds with inconceivable tightness; and it is incomparably tighter, sounder, and firmer than the oakum driven into the seams of a timber-built ship, on which the civilised world have been depending for the last couple of thousand years.

The utmost straining in a heavy sea of an iron ship, built on this principle, so long as the rivets hold the plates together, will not give sufficient alteration in the dimensions of the grooves to allow the teak to leave them, they being so firmly held in by their expansion, the dove-tail form of the grooves, and the roughness on the edges of the plates (which should be left as they came from the shears); and there cannot be the slightest doubt but that they would materially assist in keeping a ship afloat under such circumstances, in which without them she would inevitably go to the bottom. Setting aside all other advantages gained by this system, there is the most important one, which cannot be obtained by the common system of plating, viz., that the seams are secured by an additional elastic caulking by means of the teak strips.

Such a ship, well put together, the riveting firm, and all as an iron ship should only be, cannot fail to prove one of the safest structures afloat; and as a ship cannot be too tight, then if well caulked with teak, elasticity, and all that can be desired, are most certainly secured, and before long this will become an acknowledged and established fact; and it is most certain and undeniable that if any yielding or motion do take place, it can only be from the plates cracking or the seams opening, which could only result from the failure of the rivets, and this would only happen in the last extremity of an iron ship. In a sound vessel, well built and riveted, this motion is impossible. In fact, no one who has had any practical experience at sea can doubt for one moment that the elasticity of the teak would more than compensate for these extremely small movements, and that its presence in the hull would give great resiliency to the whole structure, and greatly diminish if not altogether remove the unpleasant vibration caused by the screw.

It has been confidently objected, and this too by so-called "practical" men, that by making the inside strake $\frac{3}{4}$ of an inch wide instead of 2′ 6″, the usual breadth in proportion to tonnage of ship, as shown in fig. 3, that *therefore* the ship *must* be weaker, although the sectional area of metal and mode of fastening remain precisely the same; but by none of these has any careful investigation been made of the "reason why" they promulgate this dictum, nor have there been any reasonable or sufficient data brought forward in proof.

Because the teak is placed there to hold the nails it is dogmatically asserted that it is put there to *strengthen* the ship, and that *because* teak, which is a compressible material, is put there, the ship is "immensely weakened thereby," but no calculation or proof of the truth of this has ever yet been brought forward.

Now, according to the arguments adduced by them in support of their opinion, namely, that because the "compressible material," wood, is put in the grooves, the ship *must* be weaker, it follows that if we take an ordinary iron ship of the usual in-and-out strake construction, and get a lot of dry teak planks, the thickness of the plates and the full width of the inside strakes, compress them edgeways, and then jam them into the recess formed by the inside strake (A, fig. 3), allowing the expansion of the wood to keep it in place, that the ship *must* be weaker because of the "compressible material," wood, being attached to the hull, but the sectional area of metal being the same, and no holes in the plates inside; a proposition, however, which would not be entertained for one moment by a practical man who really understood the invention, or one having any mechanical knowledge in his composition.

Mr. Grantham stated that "an iron ship would be greatly weakened as a structure if made in that form with the joints, on which I place great reliance, severed, and a soft material interposed. The size of the plate too requiring the fastenings of the zinc to be so far apart is, I think, an objection which cannot be overcome."

Mr. Lamport asserted at the Institution of Naval Architects, in 1865, that "another objection to Mr. Daft's plan is the very evident loss of strength in the ship, arising from the insertion of the bands of wood longitudinally. We all know that when a long structure is subjected to a strain in the direction of its length, every part in the middle must be brought closer and closer together with a crushing tendency; as long as the narrow surface of the iron butt joins upon iron, that tendency is met by the surface of the iron itself. Mr. Daft's plan introduces a soft and compressible piece of wood which must have a tendency to that extent to diminish the longitudinal strength. Another evident disadvantage of Mr. Daft's plan is, that inasmuch as it would have to be applied to plates ten feet long by two feet broad, the sheathing would not maintain itself on the vessel for any long time, as we find it necessary to put the nails not more than four inches apart, in order to maintain the cohesion of the copper sheathing. These points seem to me to show that though this is a very ingenious arrangement—and I must pay Mr. Daft that compliment—yet if we were to build a vessel on this principle I do not think we should find her as strong as though she were made of iron alone, and I fancy the zinc would come off in large pieces."

It is a curious thing that this latter gentleman should not have drawn the distinction between a *wooden* ship with copper or yellow metal sheathing, and an *iron* one sheathed with zinc. That a wood ship "works" and wrinkles the copper, yellow metal, or other sheathing, is well known to any one who has taken the least trouble to observe one in dock, or on a hard; and from the very nature of the vessel, being built of an assemblage of small pieces of material, *which it is impossible to fasten together with that homogeneity of structure obtainable in an iron ship, it is utterly impossible that there should be any other result.*

An iron ship will work in a seaway, but with a very different sort of action to a wooden one; in fact, were there as much "work," and of a similar character to that in a wood ship, an iron one would hardly keep afloat a single hour. From this a little consideration would have shown that he was anticipating an evil which does not and could not exist, and even if it did, or could, the mode invented by Mr. Daft would prove a complete antidote.

Mr. Grantham, who patented and advocates the building of a *double* wooden ship, or casing, one of four inches, and another of two inches thick all over the hull of an iron ship, at the moderate cost of £4000 for wood and labour, not including the copper, which wooden ship or casing has only to carry the copper sheathing, goes into some minute calculations to show how infinitesimal is the action sideways of the motion or working of the ship, on the strakes of an iron hull to cause them to open or give by the motion of the ship; and proves, apparently to his satisfaction and the advantage of his system, that this motion is inappreciable.

Now, when an engineer or practical man advances an opinion (especially where it is a decided or unqualified one) for or against any new invention which has not been tested in actual work, and consequently is in the position of not having any practical proof for or against it, it becomes his duty to give *some* reasonable and practical proof that he has good grounds for his opinion, and show to such as can understand that he is not in error, nor biassed by interested motives, and therefore capable of giving a fair opinion on the subject; there are two reasons why this should be done—first, to show that he understands the subject on which he dogmatises; and next, to prevent doing undeserved damage or injury, when a difference of circumstances would have produced a change in the course of procedure.

No doubt it may be objected by many who have not taken the trouble carefully to investigate and understand this plan of construction, that it cannot be as strong, or even so good as the ordinary "in-and-out lap" and the old "butt" system, and that because wood caulking is employed it must therefore be all that the worse.

It will be a difficult matter to convince any sensible person that planing, or chipping and filing the butt ends of the plates in each strake, fitting them neatly together, riveting up, and then caulking them, can in any way strengthen the ship, or be superior to keeping them the thickness of the plate apart, caulking them all round if desired, and filling them up with dried compressed teak. It is utterly impossible to make a strong job of an ordinary butt, and all the caulking in the world does not mend the matter; in fact, rather the contrary, as it throws a strain tending to cause the butts to open, for there is no cohesion between the ends; in fact, for all the good that is done by the caulking, the interstice might just as well be smeared over with butter.

The only valid reason for perpetuating such a faulty and unsatisfactory mode of construction, must be that which we always have advanced in favour of perpetuating evils, viz., that "it always was so," or "we have always done so;" such absurdities not being blessed with a single satisfactory or practical reason for their continuance which could convince any one with the least scientific knowledge that they are either right or ought to be continued.

Mr. Daft's mode of construction may be likened to, and embodies the principle so well put forth and advocated by Mr. Barnaby, Assistant Constructor of the Navy, in his excellent paper on "Economy of Material in Iron Decks and Stringers," read before the "Institution of Naval Architects" in 1866, namely, that of "cutting out portions" to make the rest stronger. That this is the case he fully proves, and it was admitted to be so by the Chief Constructor of the Navy, Mr. Reed, in the discussion which ensued.

It has been objected that the wood caulking is not sufficient, and would not be strong enough; but it is evidently forgotten by those who raise this objection, that if *wood* is a material strong enough to construct a ship of, and *oakum* or *worn-out* rope strong enough to *caulk* it with, that dried compressed teak expanded by the moisture and its expansion further increased by the nails holding the zinc must be tenfold stronger, and, moreover, not likely to work loose, or be affected by the water as oakum is. One great advantage of Mr. Daft's plan is, that by the use of a proper tool each seam, or edge of each plate, can be caulked as is usual with the lapped seams in iron ships, and the teak caulking applied after, thus making security doubly secure, and avoiding the use of "butts," the weakest and most objectionable portions of the hull of an iron ship.

Experience has proved that teak moderately dry, and without any further preparation, when driven into iron grooves and exposed to moisture, holds with great tenacity—in this case rectangular grooves are meant, but they may even be two or three degrees bell-mouthed or opened outwards, and yet the teak will hold in firmly under considerable strain. No under-cutting or dovetail is required under any circumstances whatever, but to set at rest all doubts on the subject, the grooves may be dovetailed by simply shearing the plates at an angle, and these grooves may be filled in solid with teak as the work proceeds, or they may be filled in with three strips, two bevelled to suit the grooves, and square on the other side to receive the third piece, namely, a tongue of teak to tighten all firmly in, and this kind of filling may be done with marine glue, or the ship may be plated and riveted, and the grooves filled in with solid pieces of compressed teak, and marine glue may be used if desired.

Teak possesses this important advantage over oak when used about iron ships—that it has no acid in its composition to attack the metal. The injury done by this acid to iron bolts, when used in oak-built ships, is well known, whilst teak, possessing as it does an oily nature, seems fitted to act as a preservative to the iron of the hull, and for this reason it is always used by iron shipbuilders.

The great firmness with which dried and compressed wood maintains its position when expanded by the moisture of the atmosphere is well known; an excellent example of this will be found in the celebrated compressed trenails and keys used for railway purposes which have been so long successfully manufactured by Messrs. Ransome and May. Another example is the plan of splitting out granite in the quarries by means of dried wooden wedges, which when driven in are either wetted or left exposed to the dew and damp, the result being the sure and speedy detachment of the desired block. An American has also applied the same principle to fixing in the handles of tools, first making them thoroughly dry, then compressing them and driving them into the socket; and these are never known to become loose.

One objection the author has had most persistently urged by one or two individuals against this system of construction is, that by keeping the plates apart at the edges or butts a great amount of strength to resist a compressive strain is lost, and that therefore any plan of construction by which the power of resisting strains is diminished must be at once condemned and rejected as useless. It will be interesting here to examine this view of the case, and see how far theory and practice agree, from which operation we shall arrive at something like a common-sense view of the case.

Ships are generally built to stand a strain of twenty tons per square inch of section in tension, and twelve tons on the same sectional area in compression. Now, as the greatest amount of strain at the butts, namely, the tensional, which tries to *pull them apart,* is provided for, and resisted by, the double row of rivets on each side of the joint, it follows that the rivets only, receive and resist the strain, and this strain be it remembered, is received on *one half* of the circumference of the rivets only. In the case of the lesser amount or compressive strain, it is assumed that the two ends of the plates being in contact increases the power of resisting compression, because this strain tends to bring them into contact, and that they assist the rivets in doing their work. A few moments' investigation of this theory will at once prove its fallacy, and show to any thinking practical man that such objections are utterly valueless and untenable. Now, as the compressive strain at the butts is received by the rivets precisely as the tensional strain, only the direction being *towards* the joint instead of *from* it as in tension, and being received on one half of the circumference of the rivets only, it follows that the rivets do the work, and, whether the butts touch or are separated, can make no difference, seeing that these same rivets in tension had withstood twenty tons per inch of section, the strain being received on the opposite half of the circumference; therefore, unless it can be proved that one side of the rivet will stand a strain of twenty tons better than the other side will stand a strain of twelve tons, this objection must be at once rejected.

There can be no doubt, however, that the *plates* will not be so rigid in compression, or so well able to encounter that strain without yielding or buckling, as they would that of tension; but assuming that they are sufficiently rigid when put together to transmit the strain of twelve tons to the rivets at the butts, then as these rivets can stand the strain of twenty tons it will be extremely difficult to show that they are less capable of withstanding that of twelve tons, or that any appreciable advantage is gained by bringing the butts into contact. It may be possible that in the case of *very bad* riveting something might be gained by so doing, but then when tension took place no advantage would or could be gained by it. No plan which can be urged in support of bad workmanship should be countenanced for one moment, and least of all in the case of a matter of such vital importance as the construction of iron ships.

Taking the case of $\frac{3}{4}''$ plates 3 feet wide, riveted with open butt joints according to Lloyd's rules, the space between two horizontal butt straps will be 28″. In this 28″ there are 15 rivets on each side of a vertical joint; each rivet is ·6″, and therefore the total area of rivets is $15 \times {\cdot}6'' = 9$ square inches. Taking the shearing strength at 20 tons per square inch of section, the ultimate strain which the rivets will bear is 180 tons, either in compression or extension of the joint.

In the case of a solid plate where there is no vertical joint, the area is $28'' \times \frac{3}{4}'' = 21$ square inches. The ultimate strength to compression being 12 tons per square inch, $21 \times 12 = 252$ is the ultimate strength of the plate in compression. The strength of an open butt joint to a solid plate is therefore as 180 to 252, or as 1 to 1·4.

This is exactly the proportion of strength of a close butt joint compared with a solid plate *in extension;* but the addition of the horizontal butt strap to the open butt joints gives a greater increase of strength to resist the compressive and tensile strain in the direction of the length of the ship, amounting to 7½ per cent. of the total sectional area. This is a clear gain in tensile strength.

Assuming that a "close" (?) butt is equal to a solid plate, this apparent objection is easily overcome by increasing the vertical butt straps so much as to take another row of rivets, the next being 8 in number, then we get 8 × ·6″ = 4·8 × 20 = 96 tons, making with 180 a total of 276 tons for a treble-riveted butt, against 252 tons for a solid plate, the extra weight of a third row of rivets being about 25 lbs. for each vertical joint. This is allowing that an ordinary "close" butt is equal to a solid plate, which, however, is never the case. If even a perfectly straight line at right angles vertically and horizontally could be accomplished, and if a *perfect* butt joint could be made—neither of which conditions can ever by any possibility exist—then even a butt joint would be weaker than a solid plate.

A common close vertical butt would, under a certain pressure from the inside or the outside of the skin of the vessel, allow of the breaking of the strap much sooner than an open butt; the latter permits of the strap bending, and the possibility of its righting itself again, but in the former case the strap is broken short in two.

Looking at the bow and stern of a ship, and taking her as running stem-on to or right against a vertical rock, it is not difficult to see that her lines—circular on plan—render every vertical joint liable to open outwards, and the straps to be broken short in two, as last described.

It is a fact that a butt joint, though most carefully made and without regard to expense, is always found to require caulking, which after all can only be done superficially, and is soon depreciated by wear; and as there is no plan yet discovered of "shrinking together" a butt joint, or increasing its stability and firmness by caulking, it remains with metal to metal no firmer or faster together than if placed simply to touch without pressure.

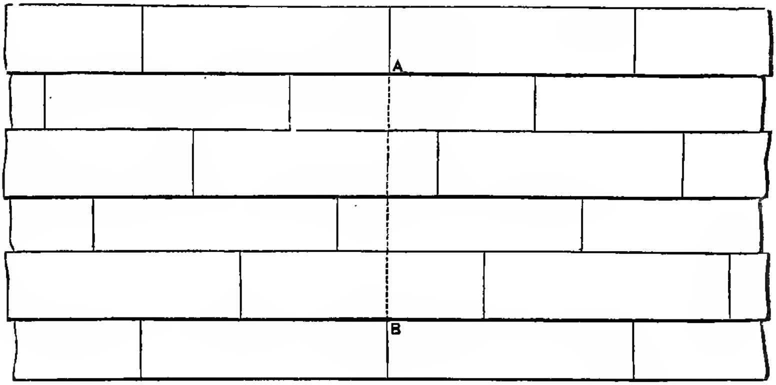
Assuming, for the sake of argument, that an open butt is weaker than a "closed" (?) one, and that an extra row of rivets cannot be added to the vertical butts, what does it amount to? Simply that there would be the vertical butts from the garboard strake to the load water-line. All above may be carried out on the plan of the orthodox butts; and if such a contingency occurred as running end-on to vertical rocks, it must, in all such cases, be the deck-line, or thereabouts, of the vessel which has to sustain or give way under the shock; therefore open butts below the water-line could not affect the case.

Further, how much of "butt-joint" work is affected by this system below the water-line? Taking a 1000 to 1500-ton ship (builders' measurement), and taking the plates at 10 or 11 ft. long, and the strakes at 3 ft. wide, we have from 370 to 450 vertical butts, according to the length of the plates up to the load water-line (of 20 ft.); so that from this it will be quite clear that the ship would find, at least, as much resistance to breaking her back on this principle as on any other.

Another great advantage peculiar to this system, in case of repairs or removing a plate, is, that with the open butt, and fair and flush plan of construction, the plating can be removed plate by plate, without disturbing or having to fit against any of the surrounding plates, each plate being distinct and separate from all the others; but notwithstanding this fact, the whole are combined as a complete skin by the butt straps.

Taking an ordinary butt joint to be as strong as a solid plate, we have through a butt joint in two strakes $2'\times 36''\times\frac{3}{4}''=54\,\square''$, then $54\times 12$ (12 tons for compression of wrought iron) $=648$. Two plates occupy 5′ 3″, vertical section $\frac{648}{5\cdot25}=123\cdot4$ tons per foot of vertical section, as usually built.

Fig. 4.



On this system, assuming the line A B, fig. 4, to be the point of failure, we have 4 solid plates and 5 butt strakes in compression, and the shearing of 15 $\frac{7}{8}''$ rivets.

$$\left.\begin{array}{ll}4\times 36''\times\frac{3}{4}''=108\,\square'' & \left\{\begin{array}{l}145\frac{1}{2}\times 12=1746\\ \end{array}\right.\\ 5\times 10''\times\frac{3}{4}''=\ 37\frac{1}{2} & \\ 15\times 6=9\times 20= & \hfill 180\end{array}\right\}=\frac{1926}{15}=128\cdot4\text{ tons.}$$

Daft's system being *stronger* than the *old* system as 128·4 tons are to 123·4 tons.

Mr. Daft, in the year 1866, read the following paper on "The Jointing of Plates in Iron Shipbuilding," before the Institution of Naval Architects, which goes so fully into the question that, by his permission, the author has printed it *in extenso*, as follows:

"The jointing of plates in iron shipbuilding admits of considerable improvement, which may be made at little or no cost.

"It is the practice now to make what is termed a "lap" joint longitudinally, or running fore and aft; and another kind of joint, called a "butt," vertically, or running in broken lines from the keel upwards. *Why* there should be two kinds of joints would not appear clear to a casual observer; but on consideration it becomes evident, and it is—because lap joints are inadmissible, vertically, on account of the detrimental effect that such joints would have upon the speed of the vessel, and not, that I am aware of, on any other account.

"Butt joints are not used fore and aft, with very few exceptions (as in the wales of large ships), because of the great expense of making them and of their extreme liability to get out of order. It will be clearly seen, therefore, that butts are used vertically, because in that situation laps are unsuitable; and it is also clear that laps are used horizontally, because perfect and durable butts in that situation are impracticable.

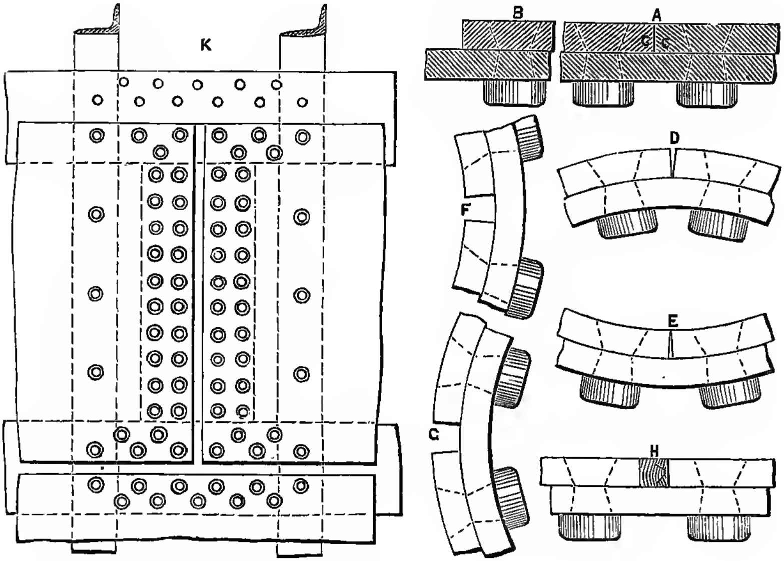
"That lap joints would always be used where butts are now, if not prohibited by the loss of speed they would occasion, scarcely admits of a doubt; for the inherent inferiority of a butt, as compared with a lap, is manifest to every one practically acquainted with the different modes of caulking laps and butts respectively. And here let it be distinctly understood that in this paper no blame is intended to be laid upon builders of iron vessels for not making butt joints that will stand the straining of a vessel in a storm without opening: it is simply impossible to do so.

"The principle of butts interdicts the practicability of perfect joints. Nevertheless credit is due to all who have laboured towards making that which in the nature of things could not be arrived at, namely, a sound and durable butt joint in the skin of a ship. As near an approximation thereto as possible has been made in all cases of good workmanship. Notwithstanding which it is the opinion of the author that the butt joints of iron vessels have been the sole cause of many fatal disasters.

"Let us analyse a butt joint, and, for the sake of argument, admit that the edges have been planed and fitted absolutely watertight (*see* A, fig. 5); in other words, that the two edges of the plates touched metal to metal throughout their surfaces, and that there was no disturbance of the parts when the riveting was done, and therefore that the caulking on the surface was done for fashion's sake, as it could not be needed if the joint was perfect without it; however, assuming an absolutely perfect joint, what is to keep it perfect in a gale? In a storm, an iron vessel opens as many mouths as there are butts.

"Again, let it be remarked that it is not the workmanship that can fairly be blamed; it is the principle that is at fault. And if the application of a principle, selected expressly for costly production, deceptive appearance, and calamitous effects, had been intended, it could scarcely have excelled that which is involved in the butt joint of an iron ship. The vessel labours, the butts open, the water enters, and the ship goes down, and all because it is physically impossible to caulk a butt like a lap at the bottom of the joints (c c). Whether the 'President' went to the bottom from this cause is a question never now to be answered; nor whether yawning butts did not give the finishing stroke to the 'London.'

Fig. 5.



a.—*Shows a common butt joint.*

b.—*The ordinary lap.*

c c.—*The bottom or root of the butt joint.*

d.—*Shows the effect produced upon a butt joint when the sides of a vessel are bulged outwards.*

e.—*The opposite effect, as when the sides are driven inwards.*

f.—*The new joint under pressure from the outside. The laps forming this joint are caulked as usual at the roots, and would consequently be tight under such a strain.*

g.—*Shows a strain from the inside with the new joint. The adhesion by reason of good caulking would probably keep this joint good.*

h.—*The new laps with parallel edges filled in with compressed teak, making a fair flush surface and a perfectly water-tight joint, irrespective of other caulking.*

k.—*A joint which is stronger than the solid plate, both in tension and compression.*

"It will be seen that with the most perfect butt that it is possible to make, there is no provision whatever for *shrinking together* and holding the joint good and close against a strain; the mere contact of the plates is all that can be accomplished, and, that done well, the superficial caulking which it afterward receives does not improve it. Let the vessel labour in a sea-way, and then, at the very moment when all her joints are wanted, if possible, tighter and firmer, the butts open and let in the water.

"In short, there are inherent evils in butts, and they ought to be abolished in favour of laps, even at the expense of speed, if it be necessary; for where so many lives are constantly in jeopardy, speed ought to be a secondary consideration. 'Slow and sure' would be a better motto at sea than 'fast and dangerous.' Yet there is no necessity to lose speed by abolishing butts in favour of the laps; they may be adopted even for vertical joints with no loss of speed or strength whatever; on the contrary, with advantage in every respect. Before introducing laps for butts, let us ask why (if butts are stronger than laps, as some persons assert) are they not used invariably fore and aft, in order that when a vessel takes the ground, and thumps her keel on a hard bottom (which happens as often as running stem-on to a vertical rock), she may have the benefit of such joints to support her? In such a case, it is convenient to think that laps are strong enough.

"Why not confess at once the truth; namely, that well-made and well-caulked laps are stronger than butts, because it is a physical impossibility to make a perfect butt, and, moreover, if it were possible to make it, it would nevertheless be impossible for it to remain tight at sea throughout a gale of wind. At the same time it would be as well to admit that, but for the loss of speed, laps (*see* B, fig. 5) would be greatly preferable for vertical joints, on account of the simple and effectual manner in which they can be made perfectly water-tight, and because they will remain so under extraordinary strains.

"Let us look at it in a new light. We should be glad of butts fore and aft, if they could be made as easily as laps, and would remain water-tight, because they would give us a flush surface and an increased speed. On the other hand, we should be glad of laps vertically, if we could get a flush joint. Now, it is not difficult to have the advantages of laps as well as of butts; the advantages of both, without the common inevitable disadvantages hitherto attending them. The plan is to adhere to laps throughout the plating, but to bring the edges of the plates so near together that, having caulked them as laps and made them perfectly water-tight, you then additionally caulk the seams with a suitable material, such as dried and compressed teak, hammered tightly into the grooves. Thus you make a second perfectly water-tight caulking of a nature that will swell under the divers strains to which a ship is exposed, and offer more obstruction to the entrance of the water under trying circumstances than any metal to metal joint. In addition to this extra and superior caulking, there is the important advantage gained of a flush surface all over the hull of the vessel.

"With regard to the supposed strength of a butt over a lap, we have the following facts to guide us (*see* K, fig. 5):—Take a butt joint of a 3-feet strake, $\frac{3}{4}$ inch thick, and consider it equal to a solid plate, then we have 36 inches × $\frac{3}{4}$ inch × 12 tons (the ultimate strength of wrought iron in compression) = 324 tons. Take a lap joint as proposed, and shown at H, fig. 5, and we have 20 rivets, then 20 × ·6 × 20 (the shearing strength of rivets) = 240 tons, and the compressive strength of the longitudinal strap 10 inches × $\frac{3}{4}$ inch × 12 tons = 90, making 330 tons for the strength of new laps against 324 tons for that of the old butts, even considering the latter as perfect as a solid plate.

"Well may Mr. Grantham say, as he does in his work 'On Iron as a Material for Shipbuilding,' 'that the lapped joint appears to be preferable to the flush (butt) joint, and it is probable that if the former principle had invariably been adhered to, much trouble and expense would have been saved, as the flush plating (butt joint) seems to have originated in a mistaken idea that it increased the strength and improved the appearance of the ship.' Nothing, certainly, can be more fallacious than to imagine that a butt joint increases the strength of the ship. By a proper system of riveting, the lap joint may always be made stronger than a butt, even though the latter be *considered* equal to a solid plate: a consideration which the author, an old boiler hand, never pays to a butt joint. What a butt loses in strength by want of caulking at C C, the root of the joint, is not taken into account in favour of laps *versus* butts. It must, however, be something worth having, in the item of adhesion.

"As to the facility of producing moderately regular grooves in the plating, by close lapping, it is only necessary to mention, what would in all probability occur to any practical iron shipbuilder, in the process of plating, that a strip or gauge of iron the thickness of the plating and a few inches wide, in fact, a strip of the plating itself, which is always at hand, is put in between the edges of the plates, while they are being fitted and marked for punching; and that if put there while the riveting is done, a moderately uniform groove is left on the removal of the gauge, depending more or less as to the correctness of the edges of the plates. If they have been planed they will be more easily caulked, as lap joints, and will receive the teak with greater freedom than if left from the shears; but if left from the shears, and irregular on their edges, the only extra trouble or expense is that of caulking, as would be the case with laps under similar circumstances. The teak is easily made to fit any irregularity of groove without the slightest difficulty, and is hammered tightly in and pared off flush, leaving a more seaworthy joint than can otherwise be accomplished.

"There are many ways of compressing teak and timber generally, but it may be well to say a few words upon teak, *per se,* before we apply it. Teak, or *tectona grandis,* is of the natural order verbenaceæ—a native of Burmah; and is abundantly met with from Ceylon to the Moluccas. In Europe, it appears of modern application to shipbuilding, but seems destined to supplant oak where stout timber is needed in iron shipbuilding. Its use for boats in its native country appears of considerable antiquity, and probably the aborigines of those parts where it is indigenous had learned by experience that it did not corrode iron. However, we know that oak does destroy iron in consequence of the gallic acid it contains, and we have found that teak is free, or sufficiently so, from that acid, and therefore produces no injurious effect upon iron when in contact with it in sea-water. But teak has another and important advantage over oak: it is, that while oak fails with a compressive strain of 10,000 lbs. per square inch, teak will bear 12,000 lbs., and may be looked upon as very nearly half as strong as wrought iron in compression.

"By comparing the structure of teak in various sections under a powerful microscope, with corresponding sections of oak, it is not difficult to see a marked superiority in favour of teak for solidity and compactness of structure. It will bear compressing when dry to the extent of 0·25 of its thickness without injury to the fibre. It has been subjected to this reduction of thickness, and afterwards immersed in water, when it has invariably returned to its normal thickness; thus it appears a very suitable wood for filling iron grooves in a ship's skin.

"There are many ways, as I have said, of compressing teak: it will be sufficient to mention one which answers very well. Assuming a $\frac{3}{4}$ inch groove has to be filled, a teak plank $\frac{7}{8}$ inch, or bare inch thick, is passed through a pair of rolls set to $\frac{3}{4}$ inch, full, and the compression is at once effected. To reduce it into strips, a set of six or eight saws of small diameters are mounted upon one spindle, with washers between the saws keeping the saws an inch apart. Running the compressed plank through these saws, cuts it at one operation into strips 1 inch × $\frac{3}{4}$ inch. No mistake can then be made even by the most unintelligent workman as to the way the teak is to go into the grooves; he will hammer it in the way it fits, and which is the way that it will swell by moisture until it is very difficult to remove it; the excess of flush teak is pared away by a plane and chisel in the simplest possible manner.

"Before the three years' experience now had with teak caulking, and before the great number of experiments which have been made with it, one felt inclined to dovetail the groove, which was easily done by shearing the plates at a certain angle, and, as the plating of the vessel proceeds, knock in from the open ends of the grooves the dried and compressed strips of teak, cut in sections to suit the dovetail; but experience has shown that teak, tightly driven into a rectangular groove, becomes a firm fixture, and is difficult to chip out. In fact, a groove may with perfect safety be two or three degrees 'bell-mouthed,' or opened outwards, and still retain teak with an immense hold when it has been tightly driven in. In case the teak be used as a medium for sheathing, every nail which is driven in tends to increase its hold by compressing the teak. If a piece of teak be fitted loosely into a groove, so that it may be removed by the fingers, after a nail has been driven into it, considerable force is required to draw it out.

"Butts may, therefore, be safely abolished in all cases and situations in favour of laps, and all laps can be made fair and flush as butt joints, the full advantages of both being thus attained by one and the same plan."

Mr. Mackrow, naval architect, observed that "The longitudinal strap is really only the usual inner strake narrowed; but considering what Mr. Grantham and others have advanced, that the vertical butts should be planed so as to make them tight, this is very much like going to the other extreme; still I believe there can be no practical objection; and I think Mr. Daft is entitled to have the opinion of practical men as to whether the system is likely to be adopted with regard to sheathing. It certainly adds a little to the weight. I have worked it out, and find that in a 1000 ton ship —of course the system need only be carried to the load line—and assuming that to be about fifteen feet, it would add about twelve tons to the weight of the ship. The extra lap, therefore, would add about 2½ per cent. to the gross weight of iron in the ship. If the vessel be made as he proposes, with the grooves, and the zinc answers the purpose, and there is every reason to believe from certain experiments that have been made that it does answer the purpose to which he intends it to be applied, then there may be a saving effected in the thickness of the plates; therefore the excess by the introduction of the extra lap may be compensated for in that way, because the thickness of the plates on the outside may be reduced. If there is no real objection to this system, and it appears to me thoroughly good at every point, certainly the introduction of the piece of teak round the centre, sides, and ends of the plates, will form an admirable method for nailing on whatever sheathing you please. I had some plates riveted together, and the teak put in in this way, and I had the satisfaction of nailing firmly into it. If we had rather a large surface of plate, say thirty-six feet, and we had to partially drill the plate to attach the centre, there might be some objection; but otherwise I think there can be none. Mr. Daft read a paper last year, but I do not think the merits of it have been fully seen or understood. I am sorry to make such a remark here, but I want you to see its practicability. I believe experiments are being tried at Portsmouth by the Government. They are not yet completed, but have been going on for nearly twelve months, to test the value of zinc in immediate contact with iron, whether, in the galvanic action set up, the excoriation of the zinc becomes equal to copper. Mr. Grantham has had his plan before the public for many years; I do not know whether it has ever been adopted. The expense of coating Her Majesty's large vessels upon that plan would be very great, whereas the expense here is very little. Ships of 3000 tons have been built flush merely to obtain speed."

Mr. John Grantham remarked, "I will just say one word with regard to the general principle of applying soft materials for the joints of iron ships. I would say, as a rule, it is undesirable, and I regret exceedingly that I cannot say or feel anything more favorable about it. I believe one great feature in the strength of our iron ships is, that they are iron and iron; that there is no intermediate material of any description interposed. We began by placing soft materials in the joints of ships, but we very soon abandoned it. It is a very old thing to try to make tight joints in iron ships by putting soft materials between them, but we found that there is nothing like iron and iron. I do, therefore, feel at the very outset that Mr. Daft's plan is not such as to commend itself for practice. Then with regard to the sheathing which, I suppose, was the real origin of this plan, I fear that that also will not be found to answer the purpose, simply because copper, and even zinc plates, require to be attached very frequently. The nails by which they are attached must be very close together, and therefore it will not be practicable, I think, to secure it merely round the edges of the plates of the hull, as the nails must thus necessarily be too wide apart. I would not say much upon this point, because I have a plan, as the world knows, of my own; but on the question of the joints I have a very decided opinion that it is undesirable to interpose anything of a softer nature than the iron itself."

Mr. Allen remarked, "I think one word may be said upon that point, that the object of introducing wood between the body of the joint is not to make the joint, it is merely to fill up the space. The joint is made by the caulking of the iron sheathing; you have iron and iron. I am not advocating the plan, but I think it is a distinction that ought to be fairly drawn; the wood is not interposed to make the joint, but to make up the surface."

Mr. Daft, in his reply, well observed, "Mr. Grantham appears to imagine that the teak caulking which is put in between the edges of the plates has something to do with the strength. Now, I do not think Mr. Grantham believes so. It is a lap joint, and it must be evident to every gentleman here, who understands what a lap joint is, and who understands the mechanical difference between a lap joint and a butt joint, that I am only using lap joints, and that the caulking has nothing to do with the strength. I think I tried last year to make Mr. Grantham understand that, and if I failed to make Mr. Grantham understand that then, that it is only a lap joint, and that the caulking has nothing whatever to do with the strength of the ship, I am afraid I never shall be able to make him understand it. Although teak is very strong, yet I would not depend upon it, because I am mechanic enough to know that to depend upon teak for strength in the skin of an iron ship would be ridiculous. But if you put laps, which surely are as strong when they come near together as when they are far apart, what is the difference between the straps which I use and the inside strake but the width? I say, when you bring the edges of your plates together to make common butts, you weaken the construction of your ship, and you *pretend* to make a joint. Mr. Grantham says the joints ought to be planed, and so does Mr. Fairbairn, and they speak very strongly on that head. If I had butt joints, and watched them every one made, and had them, if possible, watertight, so that the light should not be seen through them before they were put together, I should know that the moment the rivets were put in the joints would be broken, and that there would never afterwards, without caulking on the surface, be a watertight joint, and when you have caulked it on the surface, you have made it a delusion; you have made it appear a perfect joint, but it will open upon the slightest strain. It *does* open, and no man that we have ever heard of has found a plan of *drawing it together* and making it watertight. Therefore, I say, it is a snare, for we are led to believe that it is a perfect joint, when it is not so. I do not care what sheathing you put—put the best; but if we separate the butt-joints (which are a mockery, a delusion, and a snare) so that you can get to the *root* of the joint and caulk them, then I say, and every man who knows anything of the construction of a ship will say, that a lap joint is a much better joint than a butt joint, and that it will stand far better. It is not right to assume that any strength will be had from the teak; but caulk a lap, and you get a good deal of strength by adhesion. It is another question as to how much strength you can get by this adhesion. Make your butt as perfect as you can; spend £5 upon every butt in your ship; and I will give any mechanic in the world £5, after they are riveted, for every water-tight joint. It cannot be, gentlemen—emphatically I say it cannot be—it is a deception. Therefore, what you all well know, a lap joint is the best to adopt for caulking. Put anything else in if you like, but I think teak is the best thing; if you can press it you give it a tendency to expand when it receives moisture, and therefore you get a good hold. You do not depend upon the teak at all for strength; you have got a stronger ship before you put the teak in, and it is none the worse for having the teak. It is a less expensive mode by 50 per cent. than any I have heard of yet; I am prepared at any time to prove that. It departs less from the general construction of the ship than any other plan. It brings the work closer together; it does not give you a greater midship section; it does not give you a second ship to build; but it is all done while you are plating—it is not more costly in that respect. Mr. Mackrow has calculated—and he is very near the mark—that the extra material in a 1000-ton ship is twelve tons. It is really ten tons of material that is added; you can tell better than I can what that will cost. But is it an easier mode of building? You can set men to work at it with a great deal more freedom than you can with any other plan. You give them a strip or gauge to make their grooves by; they then put one plate against the other, with a strip between, and can mark the holes, have them punched, and it will be better and simpler work altogether. There are ten to twelve tons more of *material* in a 1000-ton ship, and it all goes to strengthen the ship."

To this it is evident there can be no valid objection; for, as Mr. Grantham has well said, "a very few additional tons make an almost imperceptible difference in the draught of water, but *materially increase the strength and durability* of the ship."

The knowledge that zinc, when placed in contact with iron, would prevent the iron from corroding and wasting away, led to the introduction of the system known as "galvanising," by means of which the protective action of the zinc was obtained for the iron by carefully cleaning it, and immersing it in a bath or vessel of molten zinc, when a coating of zinc would adhere to the iron, and thus, so long as any remained, protect it from corrosion.

This plan has been adopted for a variety of uses, such as sheets for roofing, water-tanks, chains, thimbles, &c., &c.; but, on the whole, experience has not proved it to be so valuable as at first expected, nor to be applicable with equal advantage to all the purposes originally contemplated. No doubt this may be owing in some measure to the mode in which the operation is carried out, and the care and attention given to the process.

Experience shows, however, that the mechanical application of the zinc to the iron required to be protected is more likely and certain to give the desired results than the chemical plan of galvanising, at least in the case of sheathing iron ships, and it promises to secure far more important advantages than can be gained by the chemical method.

By the use of zinc as the sheathing material for iron ships two most important advantages are secured, first the immersed portion of the ship is kept free from dirt; and the next is that the iron of the hull is kept in the highest degree of preservation, the destructive action of the water on the iron being transferred to the zinc through galvanic action.

The influence of zinc and iron in contact is so powerful that even if some portion of the iron be exposed, it will not oxidize, by the protection afforded by the galvanic influence of the other portion in contact, to those at a distance. In ordinary circumstances the atmosphere does not contain sufficient moisture to afford a conducting medium for the electricity generated; and wherever the zinc is removed oxidation will take place, but this will not extend to those parts where the metals are in contact; but where a conducting medium such as water does exist, the zinc affords protection to the iron, even to those parts at a considerable distance from the contact of the metals.

Zinc as a material for sheathing purposes has these important advantages—it is the *cheapest* material in the market; it can be *readily obtained* in *any* quantity; it is *easily manufactured;* it is *perfectly innocuous when applied to iron;* does *not require to be insulated;* can be *cheaply employed;* will *endure as long as copper;* and is *superior to anything at present known for the purpose.*

Mr. Daft, whilst perfecting his system of construction, considered many ways of fastening the zinc to the iron hull, one of which was turning over the edges of the zinc sheets so that they would overlap the edges of the iron plates and project into the groove, when the teak strips, being driven in between the overlap of the zinc sheets, would expand and keep them in their places without the aid of nails; but such grave objections were seen to exist against this plan, and several others of a similar character, and no appearance of their reliability being found which would justify their use in practice, whilst the superiority of nails for fastening was so apparent, they were at once discarded, and the use of nails adhered to.

After proving the value of zinc as a sheathing for iron in sea-water, in conjunction with the Government "Special Committee on Iron," in 1863 and 1864, Mr. Daft received instructions from the Lords Commissioners of the Admiralty, dated February 18th, 1865, to visit Portsmouth yard in order to see that certain experiments with two plates on his plan were satisfactorily made for testing the efficiency of zinc sheathing for iron ships.

Two plates ¾″ thick, 7′ long, and 3′ wide, as shown in the lithograph at page 128, were made up with ¾″ straps at the back or inside, so as to represent the actual plating of a vessel of some 3000 or 4000 tons, and grooves according to Mr. Daft's patent were left ¾″ wide between the edges of the plates. These grooves were subsequently filled in with teak strips, and the surface made fair and flush. The plates were encased in teak frames and backs, made waterproof, so that the plates should have their faces or outsides only exposed as in the case of an actual vessel.

Two of the plates had the zinc fastened in the centre, as shown by the letters A and B in the lithograph, but the other had no centre fastenings whatever, the zinc being held by the nails round the edges. A represents the fastening, which in this case was a teak plug driven into a hole drilled some depth into the plate, and a zinc nail was driven through the sheathing into the plug. B was an iron screw passing through the zinc sheathing into a hole drilled in the plate, representing the skin of the ship and tapped to receive it. c. c. c. c. c. c. c. c. were *iron* nails driven into the plugs of teak in the same manner as A. These fastenings were not needed, but from the plate having been covered all over with glue and felt, they were put in to get contact, and also as an experiment.

On the 31st of March, 1865, these plates were put into the water in Portsmouth Harbour, one at one end of the great landing stage and the other plate at the other end, where they remained during the whole of two summers until August 12th, 1866, when they were drawn up, and examined in the presence of the Lords of the Admiralty, with the results described by the correspondent of the 'Standard' in the Appendix at the end of this work.

The original intention was to nail on the zinc sheathing direct against the bare iron, in order that the contact between the zinc and iron should be perfect, and the necessary amount of electro-galvanic action should be set up when the plates were lowered into the water, to keep the zinc exfoliating or peeling away at a rate which would keep them clean and bright; but by an accident the iron was coated *all over* with a composition much used in Her Majesty's Dockyards called "Hay's glue," and a sheet of tarred felt interposed; consequently, contact had to be established by using the nails with which the sheathing was fastened on, long enough to go through the teak caulking and to turn again on the iron at the back of it. A few *iron* nails, common clouts, were introduced in order to establish firmer and more enduring contact, and to prove that they might be used, if not to an advantage, certainly without detriment to the work.

The unfortunate interposition of a substance between the zinc and the iron rendering the former liable but for the feeble action established by the long nails to foul to a certain extent, as in the case where zinc is used for sheathing wooden vessels, was a source of anxiety to Mr. Daft, and was only dispelled when, on the 12th of October, 1865, the plates were raised for preliminary examination. (They were to be kept under water for twelve months as the trial.) At the examination after six months' immersion they were found perfectly clean, though not bright, as would have been the case had the chemical action not been checked by insulation.

The zinc had not wasted enough. One ounce per square foot per annum, the rate at which it had been disappearing, was not sufficient to ensure a bright surface, a bright surface being that of all others the most to be desired for obtaining speed in iron ships and vessels. This fact, thoroughly established by Mr. Daft previously, induced him to have a third experiment (fig. 6) tried at Portsmouth, and which is fully reported upon further on. At the end of thirteen months a correspondence took place between Mr. Daft and the Admiralty as to raising the two plates, but as summer was again approaching, it was suggested by the Admiralty that they had better remain three months longer, and thus to go through another season, for the rapid growth of weeds and barnacles. This suggestion was readily agreed to by the inventor, and when they were taken up for the inspection of the Lords Commissioners of the Admiralty, consisting of Sir John Pakington the First Lord, Sir John Hay, &c., &c., on the 12th of August, they were found still in perfect cleanliness, though as before not bright. About the frame, and on the iron chains in which the plates were slung, were immense quantities of barnacles and weed, but not a vestige on the plates.

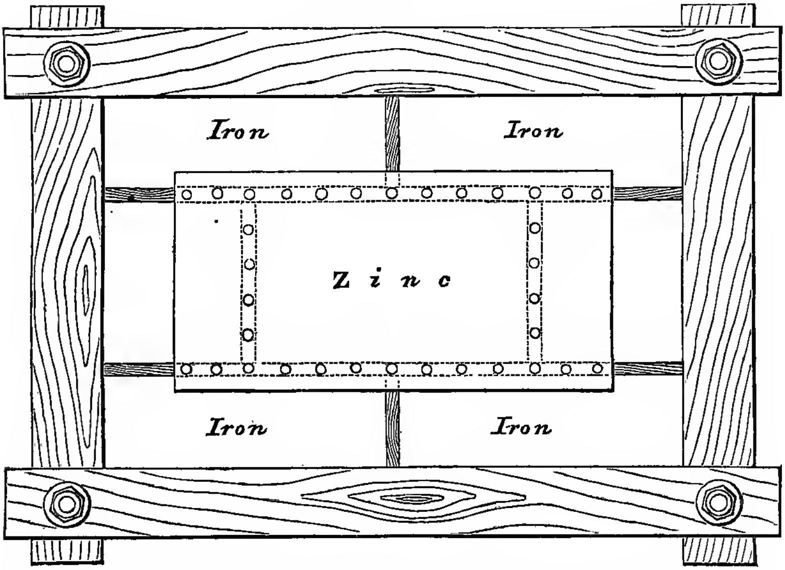
Mr. Daft then suggested that one or both plates should be stripped, and everything, zinc, nails, teak, iron, &c., thoroughly overhauled, and an accurate account taken of the loss of the zinc; and this was, he believes, with respect to one plate, done accordingly. Not that the "authorities" have furnished him with particulars at present, but, having asked for that favour, he is in hopes of getting them. However, it may be asserted without fear of contradiction, that the zinc had lost only at the rate of one ounce per square foot per annum; and it would be better to lose double that quantity.

One ounce per square foot per annum is not much more than zinc sheathing loses on wooden vessels, when a very feeble galvanic action is created—possibly at times none at all—and then fouling more or less occurs. Not that it must be supposed that fouling is peculiar to zinc alone, for other sheathings, copper and yellow metal, as has been shown in former pages, foul to the same extent as iron or zinc, or any other metal where their condition is made negative in an electro-chemical sense. If, for example, contact with iron and copper, or iron and yellow metal, be made in sea-water, then copper and yellow metal will foul rapidly at the expense of the certain destruction of the iron, then made the positive metal.

Mr. Daft thinks, in order to wear out the old wooden tubs with as little expense as possible, and yet keep them useful and safe as long as possible, that it would be wise to use iron nails and zinc sheathing—for the zinc would preserve the iron fastenings about the vessels, and the clouts (iron nails) in the sheathing would hold the zinc, and materially aid in keeping it clean by increasing its exfoliating qualities. Zinc for wooden ships under this treatment would become equal to copper and yellow metal for cleanliness, would last quite as long, and would cost not more than one third of the price.

To ensure a thoroughly clean surface the peeling away should go on at a rate of not less than two ounces per square foot per annum. At that rate it is kept absolutely bright; and if it be desired, it can be still further increased to two and a half ounces, by leaving certain parts of the hull unsheathed—for example, the keel, stern, and sternposts, &c., for by exposing a greater proportion of iron than zinc, within certain limits, the zinc is more rapidly destroyed, whilst, as has been shown in another place, the uncoated iron is, notwithstanding the want of immediate contact with the zinc, kept perfectly free from corrosion or fouling.

Fig. 6.



If zinc be used of $\frac{1}{20}''$ thick, as a good stout sheathing fit for a vessel of 3000 to 5000 tons, it would weigh thirty ounces to the square foot; and assuming a loss of two ounces per annum, and that when it was reduced to half its thickness it would want resheathing, then there would be at least seven years of a clean and safe bottom, without the slightest anxiety about it in respect of either fouling or corrosion, and no trouble or expense in docking, so long as the ship be kept off the ground and clear of anything likely to damage the sheathing.

In order that the insulation, which was likely to be obtained by the plates having been covered with "Hay's glue and felt," might not act prejudicially to the invention, Mr. Daft had a third plate (fig. 6) prepared, *without* any glue or felt on the surface, the metals zinc and iron being put in close contact, so that unimpeded galvanic action and exfoliation of the zinc sheathing might be secured.

The engraving (fig. 6) shows the form of plate, the teaking, the zinc, and the frame in which the plate was secured for immersion. This plate was put down at the end of 1865.

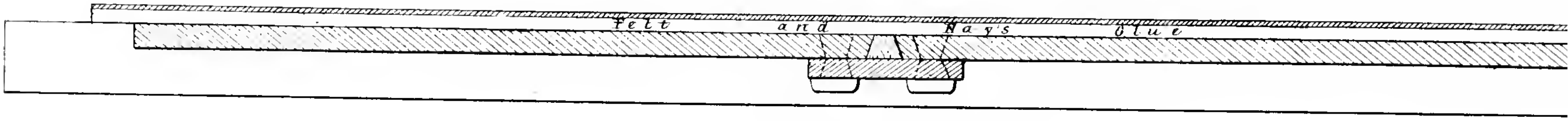
Some persons have remarked that zinc fouls, or becomes encrusted with a whitish deposit or oxide, when attached to the hulls of wooden ships, and that, therefore, such a result would be sure to occur if zinc were used on the hulls of iron ships. That zinc *does* foul on wooden bottoms is a fact; but that *because* it does so on wood it *must* on iron, is *not* a fact, nor can a single proof be brought forward to show that it would do so.

The reason of zinc fouling or becoming encrusted when used for sheathing wooden hulls, is because it does not exfoliate with sufficient rapidity to produce and maintain a clean surface, it being a less oxidizable material than copper or yellow metal when exposed to the action of salt water. On an iron hull, however, the galvanic action of the iron on the zinc produces just that amount of exfoliation necessary to produce and maintain a clean surface, and decreases the durability which, in the case of wooden hulls sheathed with it, is found to be an objection.

It has been proposed to galvanise or coat with zinc the plates which form the hull of an iron ship; and the benefits to be derived from such a course have been deemed very great. Now, so long as the zinc lasted on the plates or hull of the ship, no doubt the desired effect would be produced; but it does not seem to have occurred to the advocates of this system, that when the whole of the zinc had exfoliated, the ship would be then in the position of an ordinary iron vessel, but with this serious disadvantage, that the plates would be greatly deteriorated by the operation of galvanising, nor do they propose any plan by which the ship could be recoated: perhaps she might be taken to pieces, regalvanised, and put together again; but anyway, galvanising under such circumstances can only be called a makeshift.

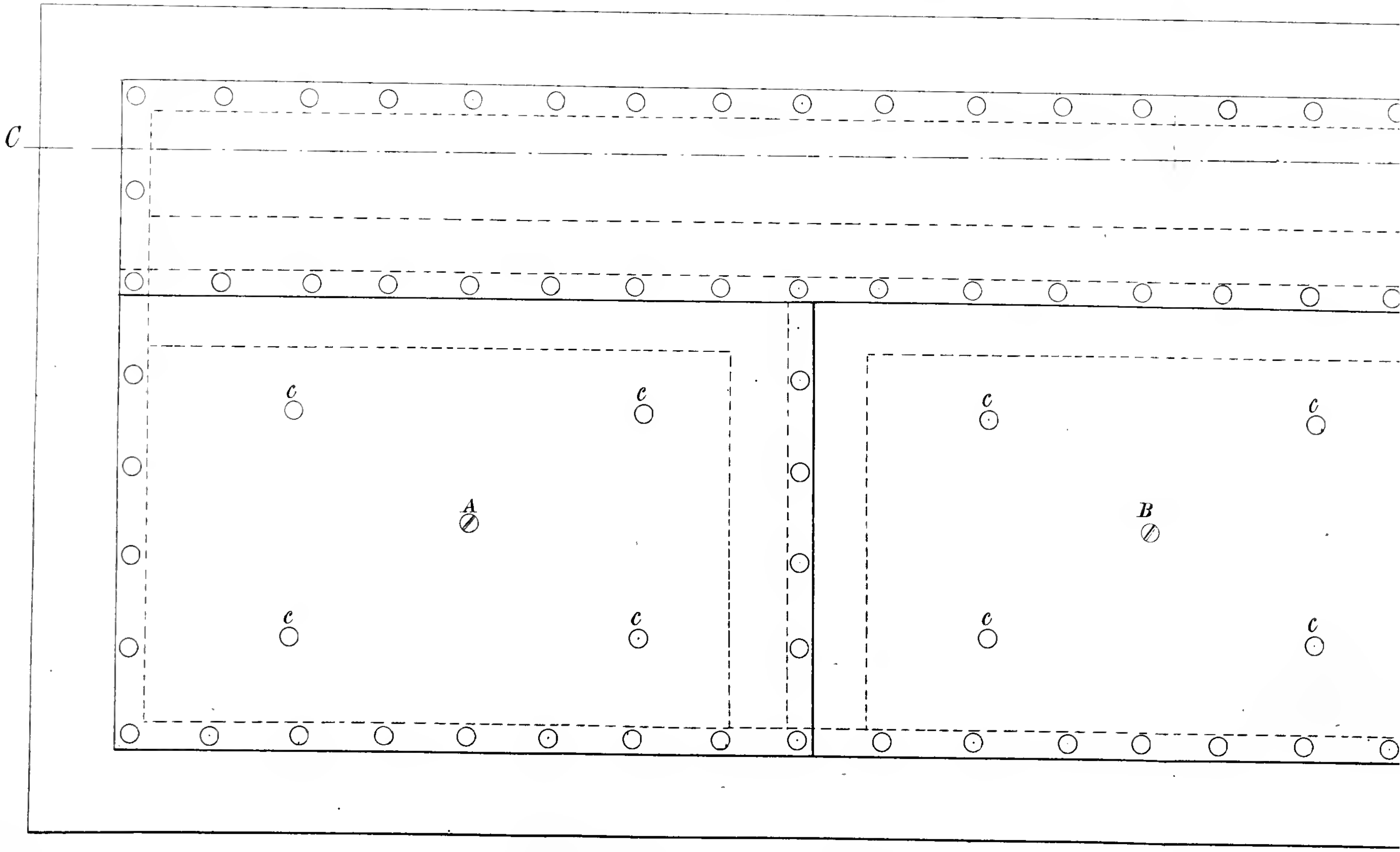
The great drawbacks of galvanising are that the zinc will peel or flake off; it does not penetrate the pores of the iron, or amalgamate

## PLAN AND SECTION OF THE
# EXPERIMENTAL PLATES ON DAFT'S
AS TRIED AT PORTSMOUTH BY THE BRITISH GOVERNMENT 18

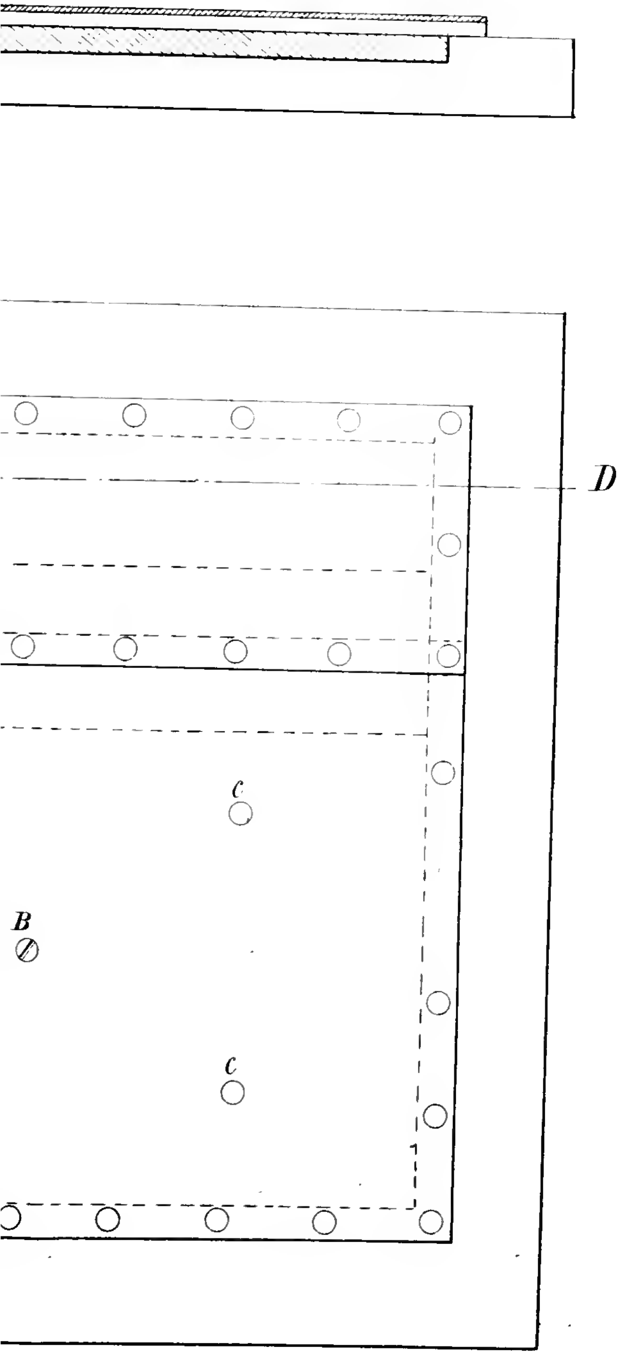


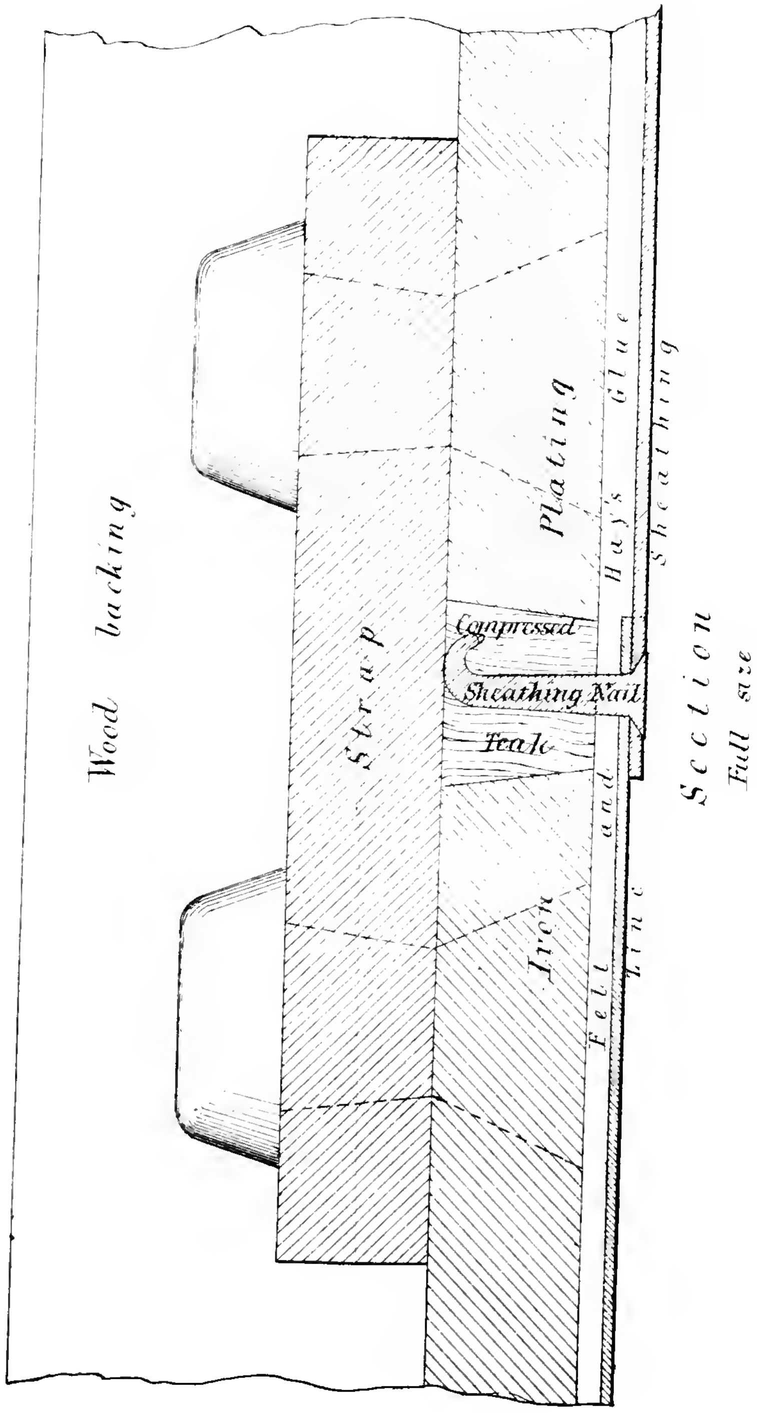
*Section on line C.D.*

*Scale 1½ in = 1 Foot*



## ON OF THE
## ON DAFT'S PATENT.
### ITISH GOVERNMENT 1865-6.





Lith.d by the London Drawing Association

with it—the operation of coating with the zinc spoils the iron; it does not last long, but soon peels off; in fact, a moment's reflection should have shown that, to be of any real utility, its application should have been so arranged as to admit of easy renewal or removal when required; and for this purpose sheathing with sheets, in the ordinary way, followed with copper on wooden hulls, would be that most certain to fulfil the requirements of the case. The author has not been able to find any proposal of *how* a ship was to be *regalvanised* after the first coating of zinc put on the plates before the ship was built had been worn off, nor does it seem to have entered into the consideration of any of the proposers that this process would require to be repeated.

Mr. Mallet has remarked of galvanising that "in sea water it is entirely useless, and as applied to iron ships it would be absolutely hurtful, because, independent of any ill effects upon the toughness of the iron, one of the effects of any partial removal of the thin surface coating of zinc is that a thin coating of carbonate of lime is rapidly deposited upon that which remains, and upon that excessively thin bed of lime, fouling takes place immediately; plants and animals readily attach themselves to it."

The late Mr. Appold remarked, at the Institution of Naval Architects, in 1861, that "the portion of the 'Great Eastern' which gave the most trouble was a portion near the rudder which was *galvanised. It was corroded all over by the action of the salt-water.*"

Mr. C. Lungley, iron shipbuilder, immediately stated that "whenever we want iron to do what we call work, we *do not galvanise it*, but if it is merely wanted to be kept clean, then we do. By galvanising the iron you open the pores of the metal, and *the tensional strength is lessened.*"

Zinc has been proposed and used as material for the construction of ships in place of iron. Some years ago (1852) M. Guibert, a shipbuilder and owner at Nantes, built a sloop of this material, which, it is said, answered so well that he built a steamer of 300 tons register also of zinc. Numerous barges and lighters are made of this material, and have been in use for many years on the continent. It is claimed for zinc, that a vessel of it will hold out over iron the advantages of more space with an equal bulk, greater buoyancy, and incalculable durability.

It will be interesting to examine the claims of zinc as a material to be used in competition with iron for building ships, and compare the results of the investigation.

To tear a piece of zinc with a sectional area of one square inch requires a force of 16,000 lbs., which will give a safe working strain of about 1¾ tons as the amount not to be exceeded.

Taking a similar section of boiler plate, we find 22 tons as the limit, which will give at a similar ratio about 5½ tons as the safe working strain. From this we get the fact, that zinc is a trifle over one third of the strength of iron; but taking it as only one half, it would follow that an iron ship of given dimensions built of ½″ plates would require, to possess equal strength, to be made of plates of zinc 1″ thick.

As to weight, a plate of iron ½″ thick weighs 20 lbs. per square foot, whilst a plate of zinc 1″ thick weighs 37½ lbs. per square foot; therefore the idea of getting equal strength with less weight, or greater buoyancy with equal strength in the same dimensions, is clearly a mistake, and it would seem to show that, except under very exceptional conditions, zinc is not a useful or economical material to be employed for this purpose, especially as we must bear in mind the difference of cost between zinc and iron. Added to this is the hitherto unknown, and it may almost be said "impossible," point, of how this material is to be put together in a manner at once simple, workmanlike, and with sufficient strength to enable a ship to be both seaworthy, safe, and cheaply and readily constructed.

The advantages of zinc as a sheathing material for iron ships are far beyond that of any material at present known; and though many fondly believe that copper or yellow metal can be used for this purpose, increasing experience and general knowledge will incontestably prove the impossibility of so doing, and the great risk of injury to the unfortunate vessel to which it may be applied; whilst zinc will daily rise in estimation, and prove itself the only metal which can be used for the purpose:

Zinc preserves iron in sea-water. It entirely prevents the rust or decay of the iron so long as any particle of it remains in metallic contact with the iron. The zinc is kept perfectly clean by a feeble galvanic action exfoliating or peeling it away. This action is caused by metallic contact with the iron; thus, in nailing on the zinc sheathing the zinc nails (where such are used) may all touch the iron, so that any sudden sweep about the hull is covered without difficulty.

Zinc is about one third the price of copper or yellow metal, is of less specific gravity, does not rank higher than iron in the galvanic list, whilst both copper and yellow metal do, and with due precaution as to the respective surfaces exposed of zinc and iron, the zinc may be made to last longer than copper or yellow metal, and keep clean all the time; therefore sheathing with zinc can be done at one third of the cost of copper or yellow metal, other expenses being the same in each case.

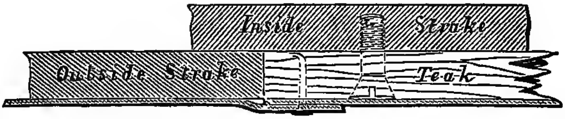
Wherever the zinc sheathing on a *wooden* ship touches the copper, yellow metal, or iron fastenings of the vessel, the galvanic action, aided by the working of the ship's hull, is the cause of a hole being quickly formed; the chafe of the water soon extends the fissure, and the result is that the sheets soon come off. From this it has been inferred and stoutly maintained by many, that a similar result must follow when zinc sheets are applied to iron hulls.

That such a result would follow in the case of an iron ship does not appear at all probable, inasmuch as the cause of it in a wooden ship would here be wanting. In a wooden vessel the galvanic action caused by the other metals, copper, iron, or yellow metal, is concentrated on a very small surface of the zinc, and there is besides this the constant working and motion of the planks and fastenings, and, as a necessary consequence, the continued frictional and galvanic action produce a small hole; but as the iron ship does not work as the wooden one, and has the surface of iron evenly exposed to the zinc, throughout the whole surface coated or sheathed with it, it is evident that concentrated and frictional action on any definite spot cannot arise or exist.

In order to sheathe ships already built, and assuming the plating to be "in-and-out" lap, as is now generally the case, a modification of the "Dafting" system may be carried out as follows:—Take teak boards of a thickness equal to the plates, and fill in the spaces formed by the *inside* strakes, so as to make a *flush* surface. The boards may run fore and aft, or they may be placed with their lengths at right angles with the keel; or they may be a combination of both ways, as may best suit the lines of the vessel, and require the least number of fastenings.

The fastenings should be screws, as shown in the accompanying engraving (Fig. 7). The inside strake being drilled about two thirds through, and tapped to suit in position and pitch two holes near the ends of each board; these, *i. e.* four screws to each board, would be sufficient to firmly hold it, if put athwartships, as its length would seldom exceed three feet, and would oftener be two feet six inches. If the boards shape better when placed fore and aft, then they may be used as long as convenient, and have a greater number of screws accordingly. The holes in the plates should be filled with tallow before the screws are put in, in order that they will easily draw when the teak should want renewing.

Fig. 7.



With a strake of teak and a strake of iron alternately, there will be no difficulty in sheathing such a hull.

Let the sheets of zinc just or barely cover in width the teak strakes of all the sheathing for those strakes; let the sheets to cover the iron strakes cover an excess in width of an inch or thereabouts on each side of them, and lap over, or over and under the teak sheathing, in order that rows of nails may be driven through the laps, and into and through the teak, and turn again upon the iron. The best nails for this purpose are common iron clouts. The zinc preserves them; they do not injure the zinc; they are tough and strong; and being well selected for length, they make superior work of the sheathing.

The serious drawbacks to this modification of "Dafting" are the drilling of the skin of the ship, and the possibility of the worm destroying the teak boards. Both these objections are entirely avoided by the system of narrow grooves, where no drilling is required, and where the strips of compressed teak are so thickly studded with nails as to defy the ravages of the *teredo.* The experiments at Portsmouth have abundantly proved this, for during sixteen months of immersion, the teak frame about the plates was much eaten away, yet the *teredo* had not made the slightest mark upon the imprisoned teak, nor had it apparently suffered the faintest decay.

This system of protecting existing ships was submitted by Mr. Daft to the Admiralty in a letter at the commencement of the year 1866.

One thing is evident, and that is, that our costly iron-clads at present constructed should have *every* precaution taken to preserve the hulls and armour-plating from decay and injury; and although the plan just described is *far from perfect,* or anything like so good a job as could be made if the hull were "Dafted," or *specially built* in accordance with Mr. Daft's invention, so as to be sheathed on his plan, still the advantages to be gained, and the *certainty* with which they must result, at any rate *without injury* to the iron of the hull, will sooner or later ensure a fair trial of this system, in spite of prejudice and indifference; and it must be admitted that even though it would not be so workmanlike a job as if the ship had been specially built for the purpose, still the certainty with which fouling and corrosion would be prevented render it worthy of adoption.

As it always happens that the most ignorant persons are the most prejudiced and dogmatical, most difficult to convince, and always desirous of having statements corroborated, it may interest such to read the opinions of the following well-known gentlemen, whose knowledge is seldom questioned, and whose capabilities in giving opinions are generally fully admitted.

No doubt a little patient study of the subject, with a desire to clearly understand the conditions involved and the results arising from galvanic action, will do much to enlighten us; still it is imperatively needful that the study should be undertaken without reference to preconceived ideas or generally received opinions, if anything like conviction and a thorough comprehension of the subject be desired.

All ideas of poisoning, the non-existence of the subtile action known as galvanic, and the unimportance of it if not largely developed, should be given up, and the matter should be studied with care and attention, and an earnest and painstaking desire to find out the truth.

Professor Faraday wrote in 1845, in his report to the Harbours of Refuge Commissioners, "It has often struck me that the cast-iron piles proposed for lighthouses or beacons might be protected by zinc in the same manner as Davy proposed to protect copper by iron."

Dr. Kane says, "Zinc *preserves* the other metals, *even if it be iron,* from oxidation."

Gmelin, in his 'Handbook of Chemistry,' states that "Zinc *completely protects* iron from sea water;" and this is exactly proved by the experiments and tests carried out by Mr. Daft and the Government.

Dr. Percy explained at the Royal United Service Institution the action of the zinc sheathing in keeping clean thus:—"The zinc is perpetually dissolving away, so that the hold of these animals is prevented. In the course of time the whole of the zinc disappears, so you see here corrosion plays a very important part."

Professor Rankine (Institution of Naval Architects, 1865) has remarked that "there can be *no doubt* that zinc galvanically *protects iron,* and also that it is, comparatively speaking, a durable material in sea water; but then comes the question of the adhesion of shell-fish and weeds. If it can be established by experiment that the galvanic contact between the zinc and the iron causes the zinc to behave in the way that copper sheathing does—to oxidize and scale off, and carry away the barnacles or other adhering bodies with it—then surely that presents a solution of the problem, provided you can find a practicable way of attaching the zinc to the iron."

Professor Thomas Graham, of the London University, has observed that "the effect of zinc in protecting iron from oxidation has been known to chemists for some time. When these two metals are in contact, an electric or galvanic relation is established between them, by which the iron ceases to be susceptible of corrosion by dilute acids, saline solutions, or atmospheric humidity."

Professor W. T. Brande, F.R.S., of the Royal Mint, observed that "in this way an arrangement susceptible of electric excitation is obtained, in which, consistently with the laws of electro-chemical action, a preservative power is conferred by the zinc upon the other metal; for in all cases in which two different metals are in contact, a current of electricity may be established in them in such a direction as to protect the least oxidizable of the two metals. In the case before us the respective metals are iron and zinc—the *iron* is the *protected* metal, and the *zinc* the *protector;* and consequently, when these combinations are subjected to the action of water and other agents, the iron is preserved from corrosion so long as any zinc remains to maintain the electric current."

Professor Crace Calvert stated, in a communication to the Society of Arts, that in 1858 he and Mr. R. Johnson "took plates of iron, and covered one surface with $\frac{1}{20}$, $\frac{1}{40}$, $\frac{1}{80}$, and $\frac{1}{100}$ of its extent of zinc plate, which we tied close to the iron plates, and then immersed them in soft and sea water. We examined these plates at the end of one, two, and three months, and finding that the zinc had exercised a very remarkable preservative effect upon the iron, we brought the matter under the notice of Mr. Robinson, shipbuilder, Newcastle, who promised to institute a series of experiments in connection with his iron ships, to ascertain whether the results we had obtained in my laboratory would be confirmed in a practical sense; but this gentleman soon after fell ill, and ultimately died."

These results left, says the Professor, "no doubt of the great protective power exercised by zinc against the corrosive action of sea-water upon iron plates;" but the conclusions he draws from these results as to the best method of practically applying the zinc are certainly wrong, and are known by practical men to be highly objectionable. He says: "I therefore think that all iron used in shipbuilding should be galvanised; and as this operation is now performed with such facility and so little expense, I cannot see any commercial objection to its general adoption."

Mr. John Bourne, in the 'Artizan' of 1844, wrote as follows respecting zinc preventing corrosion in iron ships: "With this view, the plates of the bottom should, we think, be zinked within and without. If the paint were rubbed off, the zinc would still preserve the iron; and if both paint and zinc were rubbed off the outside, the iron would still be shielded from corrosion by the galvanic influence of the zinc inside, the bilge-water being sufficient, or capable of being made sufficient to complete the galvanic circuit. To carry out this idea, it would merely be necessary to build the ship with zinked plates instead of unzinked plates, not to zinc the hull after it has been completed. It would not be necessary to zinc the rivets, as their proximity to the zinked surface would be an effectual protection."

From the discussion on Mr. Mackie's paper on "Sheathing Iron Ships," read at the British Association in August, 1866 (an abstract of which is given in the Appendix), we learn that Admiral Sir Edward Belcher said he "was perfectly sure that it must be successful."

Professor Rankine stated that in his judgment the "invention was a most valuable one, and supplied a want that was, perhaps, felt more severely than any other. By getting rid of the out seams, it did get rid of a certain amount of skin resistance." He also regretted that "so important and excellent an invention had not before this time been brought into practical use."

Mr. Galloway said that there had been "no more important subject than this brought before the sections of this Association." He hailed with "great pleasure and satisfaction the plan now proposed, as the best plan hitherto discovered of effecting the desired object."

Dr. Fairbairn, C.E., F.R.S., said it "would certainly prevent the growth of anything of the kind (barnacles, weeds, &c.) on the ship, and be a perfect success."

Mr. Abel, Admiralty Chemist at Woolwich, said the prevention of fouling "was no doubt achieved by this invention."

The President, Mr. T. Hawksley, C.E., said "it was impossible to overrate the importance of this excellent invention."

Captain H. F. M'Killop, R.N., says—"The partial success obtained with paints or compositions will not bear comparison with the success to be obtained by the use of zinc, which will very soon supersede all anti-fouling compounds."

Admiral E. P. Halsted remarks—"I have full confidence that zinc sheathing is destined to give to iron ships cleaner bottoms than ever were bottoms before."

It will be desirable here to make some remarks on the expansion and contraction of the zinc sheathing, and the iron of the hull to which it is attached. Zinc from 32° to 212° expands ·0029 of its length; wrought iron expands under the same circumstances ·0012, giving a difference of ·0017, which, multiplied by 36, the number of inches in a yard, = ·0612 in that length. Thus, it will be seen that zinc expands 3 parts in 1000, over a range from 32° to 212° = $\frac{3}{10}$ in 100, or $\frac{3}{8}''$ in 10 feet nearly. If we deduct the expansion of the iron, and take 45° as the maximum difference of temperature, we have $\frac{1}{64}''$ in 3 feet as the greatest that can happen, which amount will be entirely lost in practice in the slack of the nail-holes.

In order to test this point, sheets of zinc 7 feet long were nailed upon iron plates in March, 1865, and put under water in Portsmouth harbour. They were taken up in six months, and found perfectly flat and safe, without the *slightest appearance of bulging* or *having bulged.* Wood may be said not to shrink *endwise,* but it does shrink *crosswise.* With this irregularity of action, it retains sheathing of zinc, copper, or yellow metal, without causing material irregularity. On iron zinc lies very much flatter than on wood, and is assisted in keeping so by the regular expansion and contraction of the iron in sympathy with the zinc. The difference of expansion between the zinc and iron is infinitesimal, and not to be discovered in practice.

The following estimate of the saving in a sailing ship of 1000 tons, constructed and sheathed upon Mr. Daft's improved plan, by having no fouling or docking, has been made by a gentleman in the north of England, who has had large experience in shipping as owner:

| | £ | s. | d. |
|---|---|---|---|
| 30 men, including captain and mate . . . . | 200 | 0 | 0 |
| Food about £96, say . . . . . . | 100 | 0 | 0 |
| Wear and tear of ship . . . . . . | 50 | 0 | 0 |
| Percentage of cargo: this takes a cargo worth £20,000; that amount would at home pay interest at 5 per cent. = 1000, $\frac{1}{12}$th, being, say . | 83 | 0 | 0 |
| | £433 | 0 | 0 |

Add to this cost of docking and painting, loss of time in dock. For a steamer add monthly consumption. Working expenses of a 1200-ton ship = £600 per month, or say £500 per month for a 1000-ton ship.

1000 tons . . £500
500

£1000 Saving per month . £433
Docking and painting 150

Total per annum if kept clean for one year . . £583

The advantages gained by this principle of construction are—

1st. *More rapid and cheaper construction,* because there are no "butt" joints to be planed or chipped and fitted, and consequently no difficult caulking or imperfect joints. All the plates may be taken as they come from the shears, doing away with all accurate fitting; and as all the joints are alike and perfectly simple to make, more rapid *and cheaper* construction are thereby ensured.

2nd. *A more uniform and secure mode of caulking,* because all the joints being lap joints they admit of more effective caulking than "butts," so that by means of suitable tools the laps at the bottom of the grooves can be caulked perfectly water-tight. This is easily done by giving a slight bend to the caulking tool when necessary.

3rd. *A fair flush surface all over the hull,* which is secured by hammering strips of dried compressed teak into the grooves, which, in consequence of the expansion caused by the absorption of moisture, causes these strips to have and maintain an immense hold. This is further increased by the sheathing nails, which, when driven in, cause them to expand and hold tighter.

4th. *A good foundation for nailing on the sheathing,* obtained in an excellent manner by the compressed teak, whereby an iron ship can be sheathed with the same facility as a wooden one.

5th. *A hull perfectly free from fouling* is secured by applying a metal sheathing which avoids all danger of this annoyance. By the use of zinc the feeble galvanic action caused by metallic contact with the skin of the ship is entirely in favour of the iron; and by slightly increasing the exfoliation of the zinc its valuable qualities as a sheathing are much improved, and for iron ships it is superior to any other metal, and is the only one which can be used without causing injury to the iron of the hull.

6th. *A stronger and safer vessel.* A vessel built on this plan is stronger than the ordinary lap-jointed, or even a butt-jointed vessel. A lap-jointed vessel has been known to shear off her rivets on taking the ground, and there is always a danger of this happening in common lap-jointed vessels, whether single or double riveted, when they strike on a hard bottom.

By this system the laps are brought so close together that, in the case of a strain upon the rivets, as just described, it would be impossible to shear them off by reason of the edges of the plates touching each other before the rivets could be cut through.

The strength of the ship is still further increased by the caulking of a very hard and durable wood, viz., teak, dried and compressed and driven into the grooves, which acts as a buffer in case of accident between every edge of a plate and its neighbour, thus reducing the danger of damaging the hull of the vessel from a shock; for under the momentary pressure there will be in the teak itself a very considerable resistance to compression in addition to the hold of the rivets.

A fair flush surface for the hull of a ship would be universally preferred were it not for the difficulty of making in the usual way perfect and durable horizontal "butts;" but here the filling of the grooves with dried and compressed teak, and paring it off fair with the iron, the hull is made perfectly water-tight irrespective of ordinary caulking.

By this system all the joints, both longitudinally between strake and strake and vertically between the ends of the plates, are formed by riveting to butt straps on the inside.

The edges of the plates do not touch, but a space is left between them equal to the thickness of the plates.

Thus grooves are formed extending round each plate, and into these grooves strips of dried and compressed teak are driven forming a flush surface, and giving a firm foundation to which the sheathing is nailed.

Zinc sheathing and zinc nails are used. The sheets of zinc are made in size to suit the iron plates, and the nails are of a sufficient length to reach the iron skin of the ship and turn over at the point on touching the iron.

The nails thus driven, and the tendency of the teak to expand by moisture, secure the strips most effectually in the grooves.

The sheathing is laid immediately on the ship's skin, and being of a substantial thickness (in proportion to the durability required) it lies perfectly flat without other hold than that given by the nails round the edges.

If, however, it be thought desirable to have other fastenings, holes may be drilled partly through the iron, and plugs and nails used.

The galvanic action between the zinc and the iron is essential for the double purpose of preserving the iron and peeling away the zinc.

The action is precisely the reverse of that which occurs if copper or yellow metal be used as a sheathing, in which case the copper is preserved and fouls, and the iron, which is then the positive metal, is destroyed. Hence the importance of using zinc, irrespective of its being only about one third the price of copper or yellow metal, in order to make iron the negative and the protected metal.

There can be no doubt that this plan removes one point on which the opponents of iron ships have long taken their stand, and fulfils the wish "that no such objection as liability to fouling may remain as a handle for those who oppose the employment of iron as a material for shipbuilding."

This plan is cheap and simple, it requires no felt, no paper, no wood, no "composition," no drilling, no tapping, no insulation, but actual metallic contact; thus satisfactorily proving that the simplest plan is, as usual, the best, and most suited to meet the requirements of the shipowner and shipbuilder.

The successful action of this system, founded as it is on the unerring laws of nature, with the extra speed, the immense saving of time, the prevention of corrosion, and increased durability attained thereby, the abolition of frequent docking, its heavy expenses and loss of time, must make it a boon to all iron shipowners, and a most valuable and important adjunct to the maintenance of our naval superiority.

The advantages to be gained by constructing and using iron ships, which will remain free from fouling as long as a coppered wooden one, with the plating almost indefinitely preserved, and the hulls possessing fair flush surfaces, are so obvious, so important, and have been so long sought for, that there is no longer any reason, now that all are attained by Mr. Daft's invention, why these advantages may not be forthwith and fully realised.

The employment of the "Dafting" system will enable iron to be used for the construction of yachts, for which, up to the present time, it has been found to possess serious objections; and these have been of greater moment than its other unequivocal advantages. In fact, it has been said that if the nuisances of fouling and corrosion of the hulls of iron ships could be got over, there will be no limit to the use of iron, or the purposes to which it will be applied in ocean navigation.

The large ships used in the India and China trade which, from their fouling and corroding so quickly, if made of iron, it is now preferred to construct of wood, may by the use of this system be built of iron, thus securing the known and important advantages of this valuable material, and avoiding its hitherto serious and fatal drawbacks.

There can be no question but that this plan of Mr. Daft's will remove the greatest objections now affecting the progress of iron ships, to the great benefit of the Government, the iron trade, and the merchant service of this country.

Whatever theoretical objections or disinclination to apply this system may exist, it is nevertheless beyond a doubt that the power first using iron ships constructed and sheathed on this plan, will possess an enormous advantage, both for offence and defence; and by its use a small fleet will be quite as well able to do good service as a large one, even though it be more powerful if it be unprovided with the advantages given by this system.

The importance and advantage of being able to keep the sea, even under sail, with a clean bottom and undiminished rate of speed, seems at present to be of little moment; and that it is preferred to "find out," by contrasting inefficiency with efficiency, the advantages which it would have been wiser to have shown, especially where it concerns a matter of such vital importance.

It has been well and truly remarked, and it does not seem that it can admit of a question, that "Wherever the services of a ship of war are required, it is *indispensable* that the ship appointed for this duty should be *in all respects efficient;* the *detention of a ship for some necessary repairs may be a national calamity;* its *inferiority as a ship of war* may be attended with *national dishonour.*"

It has been asked, "After all that has been said and done by our great naval architects and builders to perfect iron vessels, what is the use of them if they cannot overtake a copper-bottomed enemy? And this would be *impossible* if an iron bottom, without sheathing had been many months at sea, however fast she might be at first."

The inconvenience, waste, and extravagance attending the carrying to sea, as stores, of paints, compositions, &c., are well known to owners, commanders, and officers of iron ships; and all of these may be avoided with many far more serious evils, and a great saving effected by the employment of Mr. Daft's simple and certain mode of constructing and sheathing iron vessels.

It has been truly said that "when men's minds are preoccupied by long cherished systems, contrivances, or modes of operation, every effort to dispel error and to introduce improvement is attended with supreme difficulty. The progress of the most practical truth is slow, although to obstruct that progress there may be no artificial obstacles."

In conclusion, it may be remarked, without fear of contradiction, that the preservation of the hulls of iron men-of-war, and merchant ships, and their maintenance in a state of constant cleanliness and freedom from fouling, are points which are of vital importance to the government, the taxpayers, the shipowners, and the sailors of Great Britain, and all other parts of the civilised world; and it must be said in the words of Dr. Latham, that "It is by your own eyes, and by your own ears, and your own minds, and (I may add) by your own hearts, that you must observe, and learn, and profit; I can only point to the objects and say little else than 'see here, and see there.'"

# APPENDIX.

THE following pages contain some articles on the prevention of fouling and corrosion in iron ships, which question the 'Standard' took up in a scientific and thorough manner; an abridgment of a paper at the British Association; the report of the result of the Portsmouth trials of sixteen months' duration; the remarks of one of the engineering papers on the principle of Mr. Daft's invention; a paper read by Mr. S. J. Mackie at the Society of Arts, the latest results of Fouling, and the progress of Improved Construction.

## OUR NATIONAL DEFENCES.

### CORROSION OF IRON SHIPS.

(*From the* STANDARD, *August* 10*th*, 1866.)

"In the conduct of every portion alike of our military and naval departments, during the past few years at least, there would appear to have prevailed either a very culpable negligence and want of foresight, or a gross ignorance of what science had discovered or had indicated. Not only have huge plated ships been built upon unproven principles, and on models against the experiences of all the nations who have been engaged in modern warfare, but although such ships are four times as costly per gun carried as our ancient boasted hearts of oak, no properly considered effort has been made to preserve them from that natural corrosion and decay which is the inevitable fate of all iron ships. What the amount of that corrosion has been, so far as the navy is concerned, we have no published means of knowing, although it is well understood to be a very serious item, and one which would astonish the British public if some patriotic member of the House of Commons would move for and get the absolute returns laid before Parliament. Merchant shipowners do not like to tell the cost at which they maintain their vessels; the late Government has so far been too adverse to letting the verity leak out, or too apathetic about the matter, or too ignorant of the real extent of the evils; while iron shipbuilders do not complain, because they get the repairs, and everybody knows that tinkering is more profitable than building. Thus it is that no one at this moment is possessed of reliable information upon this very important subject.

"But whatever the extent of our knowledge, whatever the amount of past ignorance and apathy, patriotic men of all parties will agree that in respect to the costly ships we do possess, and in respect also to those large additions to our fleets which are imperatively demanded for the security of the country, an earnest and due consideration should be given to all the means possessed and all the reasonable means proposed for preserving our iron-clads and our iron ships as far as possible from the destructive influences of the chemical and galvanic action of sea-water, as well as from the expensive waste of coal, and the dangerous diminution of speed caused by the fouling of steam-vessels through the growth of marine vegetable and animal organisms upon their hulls.

"Two topics are thus involved in this national problem—Whether the corrosion of iron ships can be prevented or diminished by any process? and whether the bottoms of such ships can be kept free from such vegetable and animal growths during long and continuous voyages? These questions ought long to have been solved; and with the resources which a Government always possesses of getting the best instruction and advice, the blame of any omission cannot be cast off from themselves by our rulers. Without doubt many difficulties have had to be encountered, many costly experiences bought, but by results alone are governments, like individuals, adjudged; and as not one of her Majesty's ships has up to this moment any efficient protection either from corrosion or from fouling, it becomes a matter of citizen duty, before the keels of our new ships are laid down, to draw attention to the subject, not doubting the present heads of the Admiralty will give every reasonable proposition careful and just entertainment. Our ancient wooden ships were protected by copper sheathing, and the numerous vessels we yet possess of that class are still so defended; but what can be done with wood cannot be done with iron. The copper sheathing can be nailed to the wood whilst it cannot be nailed to the iron. This, however, is not the most serious difficulty, and at least one effectual plan of construction has been brought before the Institute of Naval Architects which permits the attachment of protecting plates of metal with greater certainty and tenacity than is possible even in ships of the hardest oak. The most terrific obstacle has been so far the intense and rapid decomposition of the iron skin of the ship by the galvanic action of the copper and sea water. In fact, the coppering of an iron ship converts the whole machine into a gigantic galvanic battery, in which the iron being the weakest element suffers in consequence the greatest amount of destruction.

"Even a copper penny, it is said, getting into the bilge-water, has in a short space of time corroded a deep and dangerous cavity. The French have attempted, in a bungling way, to get over the difficulty by coating some of their iron ships with planking, and then nailing copper sheathing to this wood coating. Any way, this is building two ships—an outer one to take care of an inner one—and includes an expensive principle which ought never to be tolerated while there exists a possibility of obtaining any direct protection for the iron; and that such a direct protection of the iron is not beyond the possibilities of science we are convinced, if, indeed, it be not already discovered. On these points, however, the absence of sufficiently full and distinct information prevents us from dwelling with decision, and we therefore prefer to state some popular facts, and to throw out some suggestive reflections, rather than to submit any precise plans for dealing with these difficulties.

"That corrosion does take place to a large extent, the many cases roughly recorded by the newspapers are sufficient evidence; and, indeed, so great at one time was considered the evil, that the Admiralty, in 1847, contemplated the total disuse of iron, and actually commenced the sale of the iron ships then in the navy. They were changed in this determination, it is said, by the favorable results of a composition proposed by the Government chemist, but more probably were deterred from carrying out the abandonment from the impossibility of meeting the requirements of modern naval engines of offence and defence with any other material than the strong and solid metal. No one now would attempt the construction of war ships in any other material, and therefore, wasted or not wasted, iron must be used; but taking into consideration that while the wooden sailing men-of-war, which formerly constituted our proper navy, cost 1000*l.*, and wooden screw ships 2000*l.* per gun carried, the new rams are costing 4200*l.* per gun; and we may thus be satisfied of the desirability, if not the necessity, of doing our utmost to preserve such expensive vessels by every conceivable means from deterioration.

"That any application of paint, composition, or adhesive coating will never be thoroughly effectual may be well understood by every one who will reflect with due knowledge upon the circumstances under which organic fouling and galvanic corrosion take place; and the same conclusion may be arrived at by inductive reasoning from any plain narration of facts. Taking a few well-known instances will be ample to make seen the general conditions of fouling and corrosion. We have, then, the 'Grappler,' in three years from the date of her order for building, corroded with holes up to five inches in diameter; the 'Jackal,' coated with red lead in the May of one year, obliged to be docked in the April following, her bottom not only fouled with barnacles and weeds, but the plates and rivets corroded to such an extent as to make it necessary to remove upwards of 200 rivets, and to drill holes in the plates, and plug up the most cankered places. The 'Antelope,' on her return from the African coast, fifteen months from her dispatch, had more than six tons of barnacles and parasites removed from her hull, and had also corroded plates and defective rivets. The 'Harpy,' after four years' service on the American coast, was thickly covered with shell-fish and weeds. The 'Resistance,' docked a twelvemonth ago to be cleaned, had no less than twelve inches of grass in many parts, although she had been hogged within a month. Another vessel, docked last year, may be given as a further example that what was an evil in 1847 still continued so; and further illustration could be appended, if required, to show that the evil remains undiminished to the present time. The 'Royal Oak,' docked in the January of last year, was found to be 'foul beyond all conception; immense quantities of zoophytes, weeds, and corallines flourished in the wildest profusion, and so hard had the little insects formed their habitations, that nothing short of a general scraping with short scrapers would remove the incrustations—the result of six months' accumulation.'

"Such examples could be multiplied by the column; but what we have given are sufficient for our purpose. Moreover, attention has been frequently drawn to this state of things by officers of the naval and merchant services alike. It is not, therefore, to prove a case known to exist, but to illustrate the causes and conditions of the fouling and the corrosion, that we have made the selection, believing that when once the causes of any defect or injury can be clearly ascertained the remedies will very quickly be forthcoming. If any further proof of the utter incapacity of paints, varnishes, glazings, or other mere material coatings to grapple with these mischiefs be required, those who desire it have only to search over the nearly 300 unadopted patents which have been registered as preventatives.

"Taking first the question of fouling, it becomes evident that the proper protection of an iron ship must be a metallic coating, with a constantly clean and self-freeing surface. This no paint, composition, or even mere metallic or vitreous enamel will ever effect. But why this particular surface is absolutely essential becomes prominent in view of the manner and circumstances under which marine parasitic life and vegetation have their origins. In the case of animals such as cirrhipeds, balani, oysters, serpulæ, corallines, and teridines, the young only enjoy a free state, the young only are possessed of locomotion, hence the adhesion of living organisms takes place during their earliest condition as fry, and, therefore, so long as there is any permanent surface for these minute beings to get a footing on for their future growth and development, so long will some of the myriads which swarm in the sea be at hand ready to take advantage of every uncovered speck. The same with the minute spores of sea-weeds—these only ever attach themselves. Neither do such organisms or such sea-weeds derive the slightest amount of nourishment from the substance to which they are attached. Barnacles and sea-weeds are simply adherent, and whilst it is known to naturalists beyond all question that no nutriment is absorbed by either living shelled parasites or by vegetable algæ from the objects to which they are attached, it is very doubtful (except in the case of saturated wood upon boring worms) how far any noxious qualities of the material itself is injurious to the young fry when they first settle upon it; still more remote is the possibility of injury from such a source to either weeds or parasites when they have attained any considerable advance of age. For this reason alone it will be seen that the most effectual antidote to the settlement or development of any vegetable or animal growth upon the hull of a ship is the maintenance of a perpetually clean and renewed surface—such as would be presented under the condition of a continuous dissolution or a continuous flaking, by which the molecules of metal to which the organisms attached themselves should be quickly liberated from the mass of the protective envelope or sheathing, and fall away from the ship. Nothing, probably, can prevent the adhesion of parasites, vegetable or animal; and any surface which is permanent will, of course, retain whatever fixes upon it; there therefore clearly remains, as the only reasonable course, to provide some means of obtaining a constantly renewed surface. The electro-chemical action of two dissimilar metals would appear to be the most available, and, so far as our present knowledge goes, to give promise of being the most successful means of accomplishing this desirable end; and this at a reasonable and economic price.

" We have given precedence to what might, perhaps, be regarded as the minor question—the fouling of the ship—because this is an almost permanent and a really very costly phase of the difficulties to be overcome. Not only is it exceedingly expensive at all times, and particularly perilous and vexatious in that of war, to be obliged constantly at short intervals to send large ships into dock for cleaning alone, but the retardation of the speed of such vessels is a most serious item, not only in their effectiveness when brought into hostile collision with the enemy, but in involving absolutely in money expenditure a really reprehensible waste. In regard to the mere operation of cleaning, it is notorious that many of our wealthiest shipowners and some of our finest companies prefer to let their vessels run considerably fouled rather than incur too frequently the expensive operation of cleansing in dock their iron hulls. Against this it may be said that the merchant shipowner experiences an additional loss in the laying by of his ship—the most active employment of a vessel producing the most profitable pecuniary result.

"On the other hand, the immense size of our iron-clads would render delays in their getting into dock on account of insufficiency of tides constant occurrences, while similar delays would also happen in respect to their liberation. Thus long and dangerous absences would be common amongst the vessels of our fleets; and more than possibly at the very time when our utmost naval strength would be wanted, half our vessels might be away, either in dock cleaning, or returning home for that purpose, or on the voyage out again after the operation had been performed. Let us, however, look for a moment as closely as the little light that has been permitted to be shed on the subject will allow, at the money cost involved by this fouling. The 'Diadem,' 800 nominal horse-power, burns sixty tons of coal a day, and does nine knots per ton burnt. Now, if the loss from fouling amounted to one knot per ton burnt, the waste per day of steam fuel would be £14, adding to which the extra cost of wages for the loss of time on a long voyage or a naval cruise, and other items, would bring the loss to something like £25 a day. Again, if the 'Warrior,' 1250 horse-power, and burning not less than 100 tons of coal a day, should lose two knots an hour, or one seventh of her speed, by fouling, the utterly wasted cost of this deterioration of speed—for be it remembered the full quantity of combustion that would give the highest speed with a clean bottom is required to attain with a foul hull this lower rate—would be, supposing English coal were used, £30 a day; and if fuel had to be bought at foreign stations —a most probable and frequent necessity—this expense would range from any increase up to more than double. When to this cost of fuel we add wages and other incidents, we shall find that the estimate of £40 a day formed by Admiral Halsted in 1861 upon this very loss in this very vessel is really within the mark, and entirely within the actual expenditure. With thirty vessels afloat, and assuming the average loss for each as £30 a day, the total waste for the whole fleet would be £900 per diem, or £329,500 per year, from this one source of fouling alone.

"To turn now to the second and most important condition—that of the absolute corrosion and waste of the very ships themselves—we are, as we have already said, all but completely in the dark. We only know the deterioration to be enormous, but in no way can we estimate precisely its extent. We know, however, that long before the introduction of iron ships iron fastenings had to be abandoned in wooden vessels sheathed with copper; and since iron vessels have been introduced we know, too, by experience, full well that copper sheathing cannot be affixed to them without the most rapid destruction of the iron being effected. Even if the copper be insulated, the slightest accident that would bring the two metals into contact—and a portion scraped off, or battered together by a collision, or a bolt or a nail driven through, would be sufficient to do this—would set up electro-chemical destructive action; and so frequently and in so many ways would this occur, that all attempts at mere insulation would be almost certain to prove only ruinous snares and delusions. Fortunately, however, the whole question of the corrosion and non-corrosion of iron ships seems to be very simple, and very palpably comprehensible through the most ordinary knowledge of galvanic action. Iron and copper in the presence of salt water form naturally a galvanic battery, in which the iron, being the weakest element, goes to the wall, while the copper remains intact. If, then, such be the source of the corrosion, it would follow that if we can reverse the condition of the iron in respect to the other metallic element in the battery, we should save the iron at the expense of that other metal; and if in selecting another metal, instead of choosing one whose conductivity, readiness to yield to electro-chemical action or any other essential quality, favoured the greatest energy of destructive action, we took a metal possessed of such qualities in the minimum practical degree for ensuring a constant renewal of surface, we should have the best possible metal for the effectual sheathing of iron ships; and thus it would seem that science at once and directly indicates the right road to be pursued. Such a metal exists in zinc, which possesses all the requisite essentials of forming a very slowly destructible element in the natural iron-ship battery. And what is very opportune for the confirmation of this view is, that we are not wholly without experimental proof and practical experience. Any one who will simply immerse two small plates of iron and copper in dilute sulphuric acid, and two of iron and zinc in a like solution—in short, form two small batteries of those respective metals—will see distinctly the difference in the destructive action.

"Iron coated with zinc has been immersed for more than half a year in the sea, and has come out clean, while the surrounding of bare iron has been coated with organic incrustations. Zinc subjected to galvanic action in sea-water is known to exfoliate with the regularity and certainty of copper, and thus we may be assured no marine growths could find any permanent adherence upon it. As a metal for sheathing it is cheaper than copper in the proportion of from one third to one half; and as the cost of sheathing of an ordinary vessel of 400 tons with copper would be about £600, the saving in cost of metal alone in the sheathing of our entire iron fleet would be an item of national consideration. It is not, however, in mere money loss that the deterioration of the ships of our navy has to be considered. Their strength and power of resisting shot, shell, and ramming; their strength of frame to perform the dangerous process of butting, are qualities which it is essential in the very highest degree to preserve beyond all doubt or possibility of deficiency; and yet visible or invisible corrosion may be sapping the armour plates or eating into the skin of the ship; the corrosive action may be plying its vicious work around the rivets, or between the laps and joints of the plates. Dangers great and small constantly are besetting the lives of our great ships, whilst their iron bodies are undefended by any proper clothing—dangers, perhaps, often beyond the ken of the most active captain or the most efficient inspector, while the result may be that a seemingly stalwart ship may be signalled into action with flushing pride by some brave admiral only to founder with the jar of a self-sought collision, with all its hundreds of gallant seamen on board, into the watery abyss. We do not wish to predict this catastrophe, but we have a right to draw the picture. We wish to make apparent the imperative importance of the subject in every aspect.

"How far investigations have been carried in the direction we have here pointed out for remedying these serious evils it is, as in everything else connected with this topic, not easy to learn, but the path, if neglected, is in our opinion well worthy of being reopened and pursued; and whether experimentalists and practical builders hereafter prove or disprove our ideas upon the matter, it will be gratifying indeed if a few years hence we should find any effectual plan in operation, and be able to look back upon any impetus we may have been able to have given towards a fair and impartial investigation of the most suitable remedies."

The following is the report of the results of the examination of the experimental plates at Portsmouth Dockyard, as taken from the 'Standard' of August 15th, 1866:

## THE ADMIRALTY AT PORTSMOUTH.

(FROM OUR OWN CORRESPONDENT.)

"PORTSMOUTH, *Tuesday.*

"Arriving at the new coaling jetty, the board were occupied about ten minutes inspecting some iron experimental plates, prepared by Mr. Daft, to prevent corrosion on ships' bottoms. The inventor explained his theory, and pointed out the results after submersion to the First Lord, who listened patiently, and appeared interested. In your journal of last Friday was a long article on 'The Corrosion of Iron Ships,' and I am enabled to confirm the opinions of the writer on a subject he has so ably handled, and to state in addition that the question is completely solved, as will appear by the following facts which were this day brought to the notice of their lordships. Sixteen months ago two large specimens of iron-plating, three quarters of an inch thick, and about seven feet long by four feet wide, with straps at the back and grooves three quarters of an inch wide left between the edges of the plates, were made at this dockyard. The grooves were filled in with teak, and pared off flush, thus representing a fair flush surface as the hull of an iron vessel. Upon this surface was nailed a sheathing of zinc, a layer of tarred felt being interposed. These specimens, having been immersed in different parts of the dockyard, were this day raised for the inspection of the board. It is sufficient to state the result as witnessed on the jetty. Barnacles, polypi, and weed, were to a very considerable extent clustered about the frame, chains, and bare iron, but the zinc was clean, and entirely free from corrosion. Every nail head was clear and distinct, and there was scarcely the ordinary oxide of metal to cover the surface. Had such a surface as that presented been in motion, as it would have been if fixed on a ship's side at sea, it must have been as smooth as glass. The most remarkable fact related to the Admiralty by Mr. Daft was that nine or ten months ago it was thought advisable by the inventor to try zinc in 'direct contact' with the iron. Accordingly a plate was prepared with grooves in it; these were filled with teak, as before, and a sheet of zinc nailed directly upon the iron, minus tarred felt, marine glue, or any interposing material whatsoever. This plate has proved to be cleaner than the others; the extra exfoliation of the zinc, by reason of its actual contact with iron and sea-water, producing, as it does, electro-chemical action, has kept the surface of the zinc absolutely clear of oxide and perfectly smooth. This, then, the simpler plan of the two, is, as usual, the best, and the result entirely sets at rest the question of the fouling of iron ships; for while the zinc was thus kept perfectly clean, the iron was completely protected from corrosion. I am informed that there is no difficulty in using copper or yellow metal instead of zinc; but insulate these metals how you will, they have the tendency to destroy the iron skin of the ship, which is a disaster of all others to be avoided. Mr. Daft's invention was fully appreciated by the board."

## ZINC SHEATHING FOR IRON SHIPS.

(*From the* STANDARD, *August* 21*st*, 1866.)

"Those theoretical conclusions we had arrived at respecting the possibility of preserving iron ships have received in the short interval that has elapsed since their publication a most decided confirmation from our Portsmouth correspondent, who witnessed the taking up from the harbour there, in the presence of Sir John Pakington and the other Lords of the Admiralty on their recent visit of inspection, of three experimental plates of iron defended by sheathing of zinc, which had been submerged many months ago by Mr. Daft, of Chelsea. One of these plates was seven feet by four feet, and three quarters inch thick, to which was nailed a sheathing of zinc, a layer of tarred felt being interposed between the metals. Another plate the same size, and sunk in another part of the harbour, was felted in a like manner. A third, twenty-five inches by sixteen inches, was prepared at the direction of the inventor himself with the zinc sheathing in close and direct metallic contact with the iron. That we were not ourselves present on that occasion is a matter of much regret to us, as the experiments were not only of the highest importance in themselves, but such as it was most desirable should have been witnessed by as many competent persons capable of truly estimating their vast value as possible. Our correspondent there, however, was well able to appreciate their practical character, and his statements may be accepted as thoroughly trustworthy; but had we had any intimation of the circumstances we should certainly have added our own personal testimony on the subject, as some portions of the experiments seemed to be somewhat unphilosophical, and not easily explicable to an electrician at a distance. In these remarks we allude to the plates which were felted between the iron and the zinc, and which we should have suspected might have fouled unless contact had been made by the nails which fastened the sheathing, or in some other unrecorded way by which galvanic action was set up. Yet if this were so, it seems curious that an insulating material should have been put between the two metals, unless, indeed, the object were to ascertain how slight the galvanic action which would ensure cleanliness of the zinc. Government experiments are celebrated as very hard to comprehend, and as often very mysterious when comprehended. There is nothing obscure, however, about that smaller but most important plate of iron that was sheathed directly with the zinc, neither was there any mistake whatever about its superior and most satisfactory condition. This plate, our correspondent says, when taken out of the water, after ten months' immersion, 'proved to be cleaner than the others,' and the 'surface of the zinc absolutely clear from oxide and perfectly smooth.' 'This, then,' he adds, 'the simpler plan of the two, is, as usual, the best, and sets at rest the question of the fouling of iron ships; for while the zinc was thus kept perfectly clean, the iron was completely protected from corrosion.'

"The testimony of this disinterested eye-witness cannot be neglected by the great commercial and shipping interests of this country, even if the experiments themselves should be by the present Government, which we do not believe is at all likely, as our correspondent indicates that 'Mr. Daft's invention was fully appreciated by the board.'

"Since the date of our former article Mr. Daft's plans have been submitted to our careful consideration, and we have ascertained from reliable and adequate sources the actual conditions of the Portsmouth experimental plates when drawn out of the harbour for inspection by the Admiralty. We are therefore justified in drawing further attention to this most important national subject, and that it is a national subject, irrespective of any consideration of our navy, the unprotected condition of the 400,000 tons of iron mercantile shipping which are built every year in the United Kingdom is quite sufficient evidence; and still further to prove ourselves not guilty of the slightest exaggeration in the vast annual amount of tonnage, we give the quantities produced at our chief building stations during the past year (1865), notoriously a bad one for this class of business. On the Thames there were constructed 117,000 tons; on the Clyde, 120,000; on the Mersey, 80,000; on the Tyne, 51,206; on the Wear, 25,000; on the Tees, 15,000. In all, on these six rivers alone 408,206 tons of new vessels, to every ton of which Mr. Daft's excellent principle is applicable, were constructed. The world is too large and there are too many active people in it for any individual to know all that is going on, and it is therefore by no means surprising that many private experiments should have been carried out in respect to this valuable project of zinc sheathing which had not reached our knowledge. Such want of information cannot, however, be pleaded on behalf of those late Governments who have now the odium cast upon them of having spent seventy millions of money to no real serviceable end, for Mr. Daft's invention turns out not to be one of yesterday, but to have been made the subject of long-continued study and practical experiment so far as private resources would permit, and to have been actually submitted to the Palmerston-Russell Government of 1863, while in the following year some plates sheathed with zinc were immersed by order of the Iron Plate Committee, at Shoeburyness, and may now be seen at the South Kensington Museum. Neither has zinc been ultimately decisively preferred without the most careful experiments as well as mental consideration. Amongst other trials, two years ago the 'Queen of the South,' a vessel of 2000 tons, had two experimental insulated sheets of yellow metal (not zinc) attached to her iron hull, and which, after two voyages to India and back, of nine months each, remained perfectly clean. To give another case, the steamship 'Alexander,' belonging to the Messrs. Laming, of Leadenhall Street, has been no less than six voyages with two plates of yellow metal attached to her iron rudder. After every few voyages the 'Alexander' has been obliged to have her iron hull cleaned, but the plates on the rudder have remained smooth and bright; indeed, the captain has declared that the sheen of the yellow metal was always visible in the clear waters of the Mediterranean, and he could always see they were 'all right.' The insulation of the yellow metal plates—for be it borne in mind, the perfection of the insulation of the yellow metal or copper is a vital condition both for the keeping clean of the sheathing and for the very existence of the iron ship itself—was effected in a very ingenious manner. Holes were drilled in the iron skin, and plugs of ebonite driven in. Over the iron skin were then laid sheets of felt; over this again was a coating of hard india-rubber. The yellow metal sheets were now affixed by nails driven through into the ebonite plugs. After the 'Queen of the South' had carried the two plates thus secured for two voyages to India, they were turned back and both rubber and felt found to be in proper condition, and the yellow metal in as good order as if it had been on a wooden ship. Why, then, has not this method been practically adopted? Because there has always been this drawback, that metallic contact being made (by a grind against a pier or a quay, or any slight collision with another ship, or by any other common accident that should abrade the insulating material), serious galvanic action would be set up to the detriment of the iron plates of which the vessel was constructed. To put the matter in a scientific aspect, we may argue thus: iron being positive to yellow metal, if galvanic action be set up by metallic contact in sea-water, the life of the ship will be in danger; and therefore why it is that under all circumstances yellow metal should be abandoned for iron ships, and why it is policy to avoid in such vessels the use of both it and of copper.

"Having come to this conclusion, we can well understand that Mr. Daft should have sought for some other metal that was naturally positive to iron, and should have found and have proved by a number of experiments that zinc answered all the necessary conditions. Zinc, moreover, is the only metal which, possessing those particular galvanic conditions, is commercially obtainable in either sufficient quantities or at a sufficiently economic price, and zinc, therefore, so far as human prescience can foresee, must be the sheathing metal for iron ships; and if its endurance be equal on them (as there is no reason whatever that it should not) to that of copper or yellow metal upon wooden hulls, the zinc sheathing will possess the further advantage of being at least two thirds cheaper in cost than copper. Zinc, then, being preferred, operations have been carried on at Southend Pier and in other parts of the kingdom with uniformly like results, namely, that the iron when the zinc was in metallic contact was invariably preserved at the expense of some slight waste of the zinc—the very condition of things to be desired. The electro-galvanic action between these two metals in contact produces just that amount of degradation of the zinc which the copper and yellow metal have inherent in themselves, and what it is that causes them without contact with any other metal to keep their surfaces clean on a voyage.

"We are very well aware that on wooden ships zinc has been found to foul to a limited extent, being seldom as bright as copper or Muntz's metal, but in contact with iron the galvanic action is just sufficiently increased to effect that slight degree of dissolution or exfoliation which makes the zinc the equal of either in its best condition. Have we not, then, here the exact effect sought for; and in zinc a cheap commercial metal which, being positive to iron, slowly perishes itself, keeping clean and bright, while it preserves the iron—the skin of the ship?

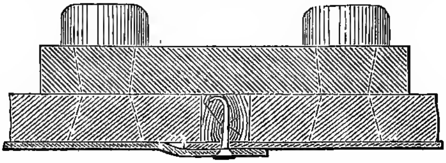
"For a time it was very doubtful if sheathing of any description could be applied to an iron ship without an elaborate process of drilling, or some other expensive expedient, but the difficulty has been overcome—and by Mr. Daft himself—as completely in the construction of the vessel, as suitable to the application of any metal sheathing whatever, by simply separating the edges of the iron plates used in the skin of the ship and caulking these joints with strips of compressed teak, the process involving less labour than the close adjustment of the ordinary butts, and giving a flush surface eminently calculated for receiving the sheathing. If zinc be used it can thus be nailed directly on the face of the iron with as much facility as upon a wooden ship; but with this marked advantage, that fewer nails are required to hold it, as the zinc sheets would be much longer than the copper sheets similarly employed for wooden vessels, while the nails, being driven into compressed teak, not only jamb tighter, but, having their ends turned by the iron overlaps of the plates, hold vastly faster than nails driven into free timber.

"Viewed in any or every way, Mr. Daft's process of zinc sheathing is one of the most important inventions that iron shipbuilders and iron shipowners have ever had to consider since the introduction of iron itself as a material for ships, and it is one which, whenever duly appreciated by those most interested classes, will lead to the largest development of the iron shipbuilding trade, as the main reasons for the retention of wood for sailing vessels will be by this means completely abolished."

## DAFT'S SHEATHING FOR IRON SHIPS.

(*From* ENGINEERING, *August 24th,* 1866.)

"In the course of our report of the meeting of the Institution of Naval Architects held in March last, we gave an abstract of a paper read by Mr. T. B. Daft, 'On the Jointing of Plates in Shipbuilding,' the system advocated being that of leaving a space between the edges of the plates, and filling it in with compressed teak, so as to afford a means for readily attaching zinc or other metal sheathing. We now give, in the subjoined figure, a section of a joint constructed on this principle, which will enable us to explain Mr. Daft's system more fully. From this figure it will be seen that the plates are placed upon the joint strip with their edges a short distance apart, and this arrangement being followed for both the horizontal and vertical joints, a groove is thus formed round each plate, having a width about equal to the plate's thickness. Into this groove compressed teak is driven, the teak, when expanded by the water, being held so tightly that it is almost impossible to remove it, except by chipping it out. The teak may be compressed in various ways, one method, which answers very well, being the following:—If the grooves to be filled are $\frac{3}{4}$ in. wide, teak planks, rather more than $\frac{7}{8}$ in. thick, are taken and passed between rollers, by which their thickness is reduced to $\frac{3}{4}$ in. full. The planks are then reduced to strips 1 in. wide by means of a set of six or eight small circular saws mounted on one spindle, with suitable intervals between them. The teak thus prepared can be readily driven into the grooves, and the excess which stands up above the level of the plates pared away with a plane or chisel.



"When the teak has been inserted, a perfectly flush hull is obtained, just as if butt joints had been used, whilst the plates may be used as they come from the shears without any after dressing. The manner in which the zinc or other metal sheathing is attached is explained by the engraving, from which it will be seen that the sheathing sheets are nailed by the edges, the zinc nails used being longer than the thickness of the teak into which they are driven, so that their points are turned over, as shown, by coming into contact with the iron skin. The teak is also tightened in the grooves by the nails being driven into it. The sheathing is laid immediately upon the skin of the ship, and at the bow and stern, where the plates are formed to hollow curves, they are, if required, secured by nails driven into plugs inserted in the iron, as well as by those around their edges, which are driven into the teak laid in the grooves.

"The protection afforded to an iron ship by zinc sheathing depends upon the galvanic action which takes place when the two metals are subjected to the action of sea-water; the zinc, being the positive metal, is gradually dissolved, whilst the iron remains intact. The rate at which the zinc is dissolved is about equal to that at which the ordinary metal sheathing wastes away on a wooden ship, and it is just sufficient to keep the bottom clean and prevent incrustation. In 1864 the Iron Committee tried an experiment on the protective power of zinc sheathing at Shoeburyness, when it was found that a zinc plate $\frac{1}{27}$ in. thick lost $\frac{1}{24}$th of its thickness when submerged in the sea for twenty-eight weeks in contact with iron. This amount of depreciation is probably less than would take place if the zinc had been fixed to the bottom of a ship in motion, but still it shows that the zinc would possess considerable durability. The zinc sheathing could be readily replaced, when worn, by stripping it off and renewing the teak in the grooves; and as this process would probably not require to be performed oftener than once in about four years, it would be less objectionable than the periodical scraping and painting now required. A specimen, representing a portion of the side of a ship as made according to Mr. Daft's system, has also been tested at the Portsmouth Dockyard, and was inspected by the Lords of the Admiralty during their recent visit to that establishment. In this specimen, which had been submerged sixteen months, felt, saturated with waterproof glue, was interposed between the zinc and the skin of the vessel, and the metallic connection requisite to enable the galvanic action to go on was effected by the nails which penetrated the teak strips. On the inspection taking place the surface of the zinc was found to be perfectly clean, whilst the enclosing frame was encrusted to a very considerable extent with barnacles, weeds, &c. As we have stated, Mr. Daft prefers to place the zinc sheathing directly upon the skin of the vessel, and by so arranging it a more perfect metallic connection is of course obtained, and the protective power of the zinc rendered more certain. We hope to hear soon of some more extended trials of Mr. Daft's system of protecting iron vessels, as it appears to be a very promising one."

The following is copied from the 'Nottingham Daily Guardian' report of the British Association meeting in their journal of August 28th, 1866—

## SECTION G.—MECHANICAL SCIENCE.

This section again met yesterday morning at 11 o'clock, when the following paper 'On Zinc Sheathing for Iron Ships' was read by Mr. S. J. Mackie:

"In science, as in life, out of troubles blessings often arise, and the philosopher, like the man of the world, by the study of the causes of temporary misfortunes, finds out the roads to permanent success.

"When 400,000 tons of iron shipping are yearly constructed at our six great building stations, on the Thames, the Clyde, the Mersey, the Tyne, Wear, and Tees, and this large quantity has to be multiplied year by year to represent only the bulk of one moiety of the enormous merchant fleets of Great Britain—when to this vast mass of British private shipping we have to add the important item of the iron-clads of our Navy—we may form some idea of the magnitude and the importance of finding some reliable and perfect means of protecting this enormous amount of property from unnecessary destruction and decay. Nor can we confine the subject within even national limits. Other countries have their iron merchant fleets and their warlike navies, and so while iron ships are sent as *iron* ships to sea with no protection from wind and water, from rust or fouling, but some utterly inefficient coat of paint, which stops not and only barely hides the mischief which is working out beneath—the question of *sheathing iron ships* is and will remain one of universal interest—an interest affecting, not only the salvation of a vast amount of wealth, but too often the salvation of many lives.

"We have long known the great extent of deterioration to which iron ships are subjected, and we have equally long known too that the rapid fouling of iron ships has utterly debarred private shipowners and our large commercial companies from sending iron sailing ships on long voyages. Wooden ships of old were subject to all the annoyances of fouling until the plan of copper sheathing was adopted—the thin coating of that metal, which possesses under the action of sea the property of always keeping a bright clean surface—why not, then, sheathe iron ships with copper? Because it could not and cannot be done. The contact of the copper with the iron sets up electro-chemical action, and the iron is destroyed; the whole ship is converted into a galvanic battery, and its iron skin perishes with more rapidity than if left alone. Still the plan was tried in many ways—the copper was insulated by wood, by gutta-percha, and india-rubber. Glass was tried instead of metal, and, like Admiral Belcher's smelling-bottle in the Arctic Seas, was quickly covered over with barnacles and weeds. So years have rolled away, and still our iron ships are sent as iron ships to sea, and—although some of our national defences cost a million of money apiece—nothing effectual has been done as yet by merchant, shipowner, or Government, at home or abroad.

"The results so recently obtained at Portsmouth from experiments upon Mr. Daft's well-considered plan of sheathing iron ships are so important that I have deemed it an absolute duty to draw the attention of this Association to them, and particularly also to the whole system of zinc sheathing, and to the novel method of putting together the skin of the ship by which the zinc or any other metal plates can be directly applied to its surface.

"I alluded in my opening words to the advantage to philosophers of misfortunes. Mr. Daft, like a true philosopher, has converted the knowledge of the cause of the great evil in iron ships into the best and most reliable means for their protection. To cure evil we must do good, and the good is the reverse of the evil. Just so, with the greatest simplicity of thought (for all the sciences, like truth itself, are simple and comprehensible by all), Mr. Daft has argued—If the galvanic action set up by salt water between copper and iron causes the accelerated destruction of the iron, could we not, by substituting for the copper some other metal which should stand in galvanic relationship to the iron as in the former case the iron stood to copper—that is, if we could find a metal which should be electro-chemically positive to iron—we should have a galvanic battery constituted by the ship and the sheathing, in which that sheathing would be the element to be destroyed and the iron the element to be preserved. Now, there is but one available metal that would effect this end, and that is zinc, a metal commercially much cheaper than copper. Will zinc, then, do for sheathing? Will it decompose too fast and require too frequent replacing? or will it not decompose fast enough to prevent fouling? These questions Mr. Daft set about to solve by practical patient experiments, in the same quiet, simple, satisfactory natural way as he first conceived the original idea. The author then showed clearly the difference of effects produced by the actions of salt water upon copper and iron and iron and zinc respectively, in metallic contact, by exhibiting small strips of those metals which had been immersed in two glasses of salt and water the day previous. The results, by a happy accident, Mr. Mackie was able to make visible to the meeting. To bring the plates to the meeting he had wrapped the two pairs of elements in separate papers, and those which had constituted the copper and iron battery had during the few minutes of their carriage to the meeting-room deeply stained the enveloping white paper to a deep red ochreous tint, while the papers containing the iron and zinc elements, although subjected to exactly the like treatment, remained free from any visible stain whatever. Mr. Mackie then pointed out in detail the method which had been proposed for constructing the skins of iron ships, in such a manner that by caulking the seams with teak a perfect water-tight joint was made, and a plane flush surface secured for the whole hull of the vessel. He also showed that fouling would be prevented entirely by this process of zinc sheathing, because the galvanic action of the iron and zinc in sea-water secured sufficient exfoliation of the exposed surface to keep the zinc as clean upon an iron ship as copper on a wooden one. He also described the practical experiments which had been made at the direction of the Admiralty at Portsmouth, where zinc-sheathed iron plates, which had been submerged in different parts of the harbour for from ten to sixteen months, had been taken up during the past month in the presence of Sir John Pakington and other lords, with not only the iron perfectly free from corrosion, but the zinc sheathing bright and clean, without any barnacles, weed, or other indications of fouling whatever. These and many other details were given in simple intelligible language, and were illustrated by an actual riveted specimen, some two feet square, caulked with teak and partially sheathed with zinc, representative of the actual skin of an iron ship. The speaker further indicated how the galvanic action between the iron skin and the sheathing could be modified to any degree of required intensity of galvanic action, and how builders could form flush hulls upon this plan without its being necessary to plane the edges of the iron-plates to absolute smoothness, as was now obliged to be done in making 'butt' joints. And now, he concluded, having briefly, I hope intelligibly, put before you the methods Mr. Daft has devised, and which, after mature consideration and experiment, have been found to possess a real and meritorious value, I would urge that the greatest good that can be done to his plan is to detect and criticise every point that seems not merely defective, but to fall short in any way, however slight, of absolute perfection for the purpose for which it was devised—knowing full well that Mr. Daft has refrained from putting his views too quickly before the world—preferring to spend money and time upon satisfactory proof and satisfactory investigations, so that at last he might come forth with his methods substantiated in their value by those best of credentials—the record of practical tests; for whatever shortcomings or omissions there may have been on my part, for whatever further may be desired to be known by any one, every possible facility for information will, I am sure, be given by Mr. Daft, whose most earnest desire now is that his inventions should be convincingly proved to be the proper means of preserving iron ships, and be adopted by shipowners and builders and the Government. And here, in conclusion, let me add that, as the retention of wood as a material for the construction of ships going to India, China, Australia, and other long voyages, is almost entirely due to the present absence in use of any means of preventing fouling except by *copper or yellow-metal sheathing,* which from their destructive action cannot be applied, so the furnishing of a reliable means for putting on a safe and clean-keeping metallic sheathing will add to the present iron shipbuilding trade—will double the amount of business by bringing into the hands of the iron shipbuilders the construction of the necessary means for carrying on all our great national distant commerce. To this the highest scientific court in the world—if it approves the principles Mr. Daft has worked upon—I would modestly put the vital question, Can a better means be devised than one which nature herself constantly manipulates?"

## OUR NATIONAL DEFENCES.—THE CONSTRUCTION OF IRON SHIPS.

(*From the* Standard, *Monday, September 24th,* 1866.)

"The paramount necessity of a thorough examination into the state and condition of the British Navy being evident beyond question, and now not only generally acknowledged by all parties, but the investigation being actually undertaken by the present head of the Admiralty, it is desirable that attention should be drawn, before any decisive steps for reorganisation and construction are determined upon by the Government, to every topic of importance in the construction of iron ships. Wood is a material of the past, and with its abandonment for war vessels all the experience of bygone times has been cancelled, and men have had, and still have, to deal with new requirements, new difficulties—to struggle through many dilemmas, and, as in all new operations, to wade through innumerable trials and failures in the progress towards ultimate success. That ultimate success in iron shipbuilding is not yet attained. We do not speak now of those debatable matters—broadside ships versus turret ships, or of towering 'Northumberlands' versus skulking 'Miantonomohs' and 'Monitors,' nor of wave lines nor wedge lines; neither have we here anything to do with armour-plating or the stopping out of shot and shell; but we speak absolutely of the construction of the ship itself, whatever her form or shape or requirements may be—the way, in fact, in which the skin plates of iron ships are put together.

"That there are serious and grave defects in the putting together of ordinary commercial iron ships every conscientious builder must admit, and every novice even can see of this in almost all the merchant vessels afloat conspicuous evidence, if his attention be directed to it. In almost every iron vessel he will see the plates riveted together in two different ways; he will see the longitudinal strakes have the edges of their plates lapped over each other, and the rivets driven through both inner and outer plates, the contraction of the heated metal of those rivets (which are driven in red hot) in the cooling bracing together firmly the plates, and holding them in a mighty grip that makes the 'lap-joint' stronger even than the plate itself. In almost every vessel we see in the longitudinal seams these lap-joints used; and although this practice necessitates an irregular surface for the skin of the ship that militates against her speed, the 'in-and-out' strake system is so common as to be almost universal, while a smooth or 'flush' sided iron ship is a comparative rarity. But in all iron vessels we find, further, that although lap-joints invariably form the horizontal seams, another kind of joint is employed for the vertical ends of the plates. These terms, horizontal and vertical, are used here expressively with a good deal of latitude, for in reality there is no true horizontal or vertical line in the entire skin of a ship; and what in the side is vertical will be under the bottom, of course, of all degrees of inclination down to absolute horizontality. The term horizontal we apply, then, to all joints or seams running in directions consonant with the length of the ship; and the term vertical to all joints transverse to these, or in directions from the keel towards the bulwarks above. These terms have crept into general use from the natural habit of speaking of what we can best see, namely, the midship side of the vessel that is out of or above water. In those joints of the plates, then, as we have said, which run from end to end of the vessel, the sides of the iron plates of one strake are lapped over the sides of the plates of another strake, and the rivets driven through the edges of both. But in joining the ends of the plates in these same strakes a totally different kind of joint is used. The vertical edges of the plates are not here lapped over each other, for the abrupt ridges that would be thus created would offer too much resistance to the passage of the vessel through the water, and therefore the edges of the plates are merely brought as close as possible against each other—butted, as it is technically termed—and back straps are riveted on to hold the plates in place. These butt-joints are a source of eternal trouble in merchant ships, and are a source of still more serious anxiety in men-of-war of all sizes and classes. Every pains has been taken, every effort made, by builders to close up and secure these butt-joints, but without avail; every iron vessel that comes into dock shows something wrong with her butt-joints. In the best yards the edges of the plates are planed smooth, so that they shall fit as exact as possible, but no sooner are the rivets driven than the edges shrink away from each other and an evident crevice appears between them. Then these butt-joints are caulked—that is, the edges of the adjoining plates are driven up together by hammering with a steel chisel, but close as they may be driven, there is still no welding, and the bringing together of the metal is only a hiding of the difficulty and the danger, for the operation is little more than surface deep. Tight, however, as the edges may be driven together, no sooner is the ship afloat than her every twist and strain tends to yaw open the butt joints, and if the tensions be very great, and constantly varying, as in a storm, hundreds of these narrow mouths are gaping to suck in the destructive element, and the iron ship founders at sea. Everywhere in such a case, as one of the passengers of the ill-fated 'London' wrote, 'everywhere the water pours in,' for everywhere all over the ship there are butt joints to tear and bend apart. In an ordinary merchant vessel of 1000 tons there are 400 of these butt joints unceasingly liable to disruption; but in one of our great iron-clad men-of-war there are no less than from 900 to 1000 such joints, all much more liable to split apart on account of the momentum and weight of the heavy armour attached above and below the water-line to the skin of the ship.

"It rarely happens to a man to make two distinct important inventions, and yet it not unfrequently happens that subsidiary to one good thing another is necessitated; and this has occurred with Mr. Daft, whose admirable and simple plan of zinc sheathing for the preservation of iron ships we recently noticed. To give for the zinc sheathing some firm and convenient means of attachment to the hull was not, as ships have hitherto been built, a very easy task. Doubtless it could be done in a more or less effective manner, but still it would not be a perfect job. There was, then, a necessity for devising some new and superior means in the construction of the ship itself, and Mr. Daft has proposed to open all the joints and leave a space of an inch or more all round the plates, each plate being joined to the other by a narrow back-plate to which each skin plate is riveted by an overlap joint identical with the lap joint of the longitudinal strakes, in this way substituting for the objectionable butt joint, what we may term, a double lap joint all over the ship. This novelty in shipbuilding—and that a novelty it is there can be no question, for iron ships cannot be constructed in secret, and everything that has to be done is patent to all the world —we deem of such importance as to lay special stress upon it in this article, being satisfied that no valuable improvement will, under the better spirit which now prevails at the Admiralty, be treated with that indifference which during some past years has been so keenly complained of. The Herculean task which Sir John Pakington has entered upon, and which the national safety demands should be carried out to the utmost of effectiveness, is a duty in which we have reason to believe the First Lord of the Admiralty will be cordially supported by those heads of departments whose official experiences will be no mean assistance to the best ability and the best endeavours.

"Moreover, beyond the actual superiority of safety, the saving of expense by the use of the double lap joint for such vessels as the 'Northumberland' would be no mean item; for in Mr. Daft's joint it is not required to plane the edges of the plate to a mathematical fit; it is not even required to plane them at all; and as the present most careful planing and fitting performed at our national dockyards costs over 2*l.* for each butt, the saving would amount in a single ship to more than 2000*l.* It might, however, be urged that our large iron-clads are so harnessed in armour, have the skin of the ship so supported and strengthened by the exterior armour-plates and their backing of timber, all riveted, and braced, and bolted together, that the outer fabric is made so stout and so rigid, that the inner and proper skin only constitutes a small item in the external hide of the vessel. But this would be a grave mistake, and yet it is one constantly made by writers who criticise the works of naval architects and the qualities of ships and ship batteries, without ever having seen a ship built, and perhaps without having been on board one. Neither is it an uncommon mistake made in society to suppose that the whole skin of an iron-clad is made of unusual thickness and solidity, many persons forgetting or not knowing that the under-water part or bottom of the iron-clad ships of is thin iron, such as would have been used had the vessel been an ordinary one; but this thin iron is strengthened by a webbing of deep flat ribs, extending from the outer to an inner iron skin, all being brought up to a flat ledge, upon which the armour-plating and its backing (which only extends as a belt round the ship for some feet above and some feet below the water-line) is rested. As much thinness as is barely consistent with safety is, therefore, adopted for the plates forming the under-water hull, in order to diminish as much as possible the weight of iron used in the ship. In point of fact, the designer of an iron-clad may be said to take off as much iron as he dare from the general hull of the vessel, in order that he may put as much armour as the flotation will allow round the ship's water-line and battery. All the evils, therefore, that an ordinary ship is subjected to, and especially that most serious one of all, the yawing open under her strains of the butt joints, are vastly increased in an iron-clad by the momentum and weight, and even the rigidity of the armour-band around the ship; and the thicker and more rigid the armour applied, the worse the strains upon a thin-skin bottom will be in their effects upon the joints.

"There are anomalies, moreover, in iron shipbuilding, as in every other branch of practical science. The tensile strength of an iron plate is greater than its strength when in compression. Under tension, the iron plate requires a strain of 20 tons to the square inch to break it; but 12 tons in compression is enough to crush it. The strains, too, upon the skin plates of a ship are as different in value as they are in their character; and as there are two kinds of joints, the effects of tension and compression will be differently manifested in their influences. The lap joints, themselves as strong as the plate, are always subjected to tension, and never to compression, because, come which way the strain may, it always exerts a tensile pull upon the plates and a shearing strain on the rivets. The butt joints have no value in tension, but are subject to compression, and then the worst joints in the ship have to sustain that strain to resist which the iron plate itself is least competent. For as the shearing strain, or that strain which will 'shear' off the rivets, is 20 tons to the square inch, it is equal to the breaking tensile strain of the solid plates themselves; whilst, when the ends of the skin plates are in abutment against each other in the butt joint, the breaking strain of the solid plates by compression is 12 tons, and therefore the strength of the hull of any vessel having butt joints must be regarded at the lesser value of 12 tons to the square inch, and not at 20 tons, as it might be if all the joints in the ship were lap joints. But there are still other points to consider in the vibrations and torsional strains to which iron ships are subjected. We have spoken of 12 tons as the limit of the compressive strain; but this, it must be remembered, is the limit when the plates are perfectly straight and brought fairly in opposition—conditions which, it may be said, never happen in a ship, every line of which is a sweep of greater or less deviation; and the consequence, therefore, of the butt joint is, that the skin plate yields by buckling at a still lower strain of 6 or 7 tons to the inch, while the leverage of the buckling is exceedingly likely to snap off the rivet-heads. In order best to understand the difference of strength between a butt joint with a back-strap, and a double lap joint riveted to a narrow back-plate, let us suppose the butt joint and its back-strap to be one solid homogeneous mass of metal. Would anybody be mad enough to cut the joint half through with a saw? Nevertheless, this half-cut-through joint would be all but identical with the ordinary butt joint. Any one would see, if the solid joint was half cut through, that at every bend of the ship the cut would be liable to be opened, and that every opening would be likely to rend further and further the gash. And this is just what happens when the butt joint is made to yaw by the snake-like torsions of a ship labouring at sea. All the leverages of the two plates are brought to bear upon the back-strap at the line of the butt joint, and all the resistance is thus made to fall solely upon the line of particles in the back-strap opposite to that joint; the more perfect, therefore, the butt joint is made to keep out the water, the more smoothly it is planed, the more closely it is fitted, the more dangerous is its tearing tendency upon the back-strap, and the more dangerous its real character in respect to the safety of the ship. On the other hand, by separating the edges of the plates but a single inch, we have done away with the butt joint, we have done away with the dangerous crack, we have made two of the strongest kind of joints (lap joints), instead of one of the weakest, and have allowed a sufficient interval of metal between them to bend into a curve when the strain comes upon the back-plate, and to bend back again into position when the strain is released, if the metal possesses sufficient resilience to do so. We have, in short, produced a very narrow strake, which we can iron-caulk first if we please, and then fill up with an effective caulking of wood, not only to nail the zinc sheathing to, but to complete a watertight joint; at the same time, the whole hull of the ship is completed flush and fair from one end to the other in every direction alike—a consummation never yet accomplished, nor possible, under the former procedures in building, except at a dangerous and unwarrantable use throughout the entire vessel of the untrustworthy butt joint. That the number of joints is increased under Mr. Daft's plan is no detriment to the vessel; on the contrary, it adds to her stiffness; and the cost of any additional metal and riveting is more than compensated in the saving of labour and machinery for planing the plates. Moreover, the actual weight of the slight additional quantity of iron required for the back-plates is also more than compensated by the increased capacity of the ship; for in the bringing out of the in-strakes to flushness with the out-strakes there has been the gain in every other strake of the thickness and width of an entire strake to the internal dimensions of the ship, and, consequently, an equivalent increase of her buoyancy. Thus constructed, there are no inequalities whatever in her skin to interfere with her speed through the water, nor any ledges to form first shelters for the attachment of weeds and barnacles.

"The remarks we have made so far apply equally to iron shipbuilding for the merchant service as for the navy, as indeed will most of the comments we have hereafter to make. There are some points, however, which apply peculiarly to men-of-war, and others which have more pointed force in respect to them than to any other classes of vessels. In respect to iron-clads we have seen how essential it is in every way to give the greatest strength to the proper skin of the ship in order to support the armour-plating as well as to resist the strains upon the hull below water, where the greatest yawing action will necessarily take place. And yet we have seen, too, that this very under-water portion is purposely kept as thin as possible to give more flotation power to the ship. How vital then in importance is the plan of any joint which, without increasing the thickness of the skin by a single line, should raise its breaking strength from 6 or 12 to 20 tons the square inch of metal.

"Nor in this consideration must we overlook another important feature of strength or weakness in an iron ship—the riveting. Whatever may be the quality of our plates, however high their tensile or compressive resistance, all may be set at nought by bad or defective riveting. And to rivet well large plates under the system of in-and-out strakes, now so universally prevailing, is no easy or generally accomplished matter. The large skin plates of one strake have to be held in place against those of another strake already fastened to the framework of the ship, and the rivet-holes of the attached plates have to be marked through their punched holes (or a similar process adopted) upon the plates next to be fitted. The plates so marked have then to be held under the punching machine, and each mark has to be punched as near as men's hands will guide great plates 10 ft. × 3 ft. under the punches. It is very easy to believe that under these circumstances the rivet-holes of the plates of one strake do not always properly 'look at' the rivet-holes of the plates of the other strake that are to come over them; and that the practical consequence is either that smaller rivets than the diameter of the punched holes are used, or that the punched holes are 'rhymered' or opened to admit bigger rivets, which are often driven in in a contorted form, or with only half their proper diameter coming fairly through both plates, and thus being seriously weakened in their strength. Under Mr. Daft's plan all the large skin plates of the ship can be punched with rivet-holes by a suitable adaptation of the machinery at mathematically accurate distances apart; and after they are fitted to the ribs of the vessel it is evident that the holes of the handy-back plates can be so exactly punched that when they are fitted to the skin plates every rivet-hole will be so truly in position with every other that the professional 'squarer' will have a sinecure office in all but his inspections.

"Two decisive advantages are thus derived entirely from this simple but ingenious plan of double lap-jointing the skin plates on to a narrow back-plate, namely, the full strength of the iron plates is brought out, and the strength of the ship most materially increased without any increase whatever in the dimensions of the skin plates; and secondly, the perfection of the riveting is ensured, thereby getting rid of a serious danger that in ships as now constructed is only masked from eyesight and inspection, and is all the more treacherous that it passes uncared for in a fallacious belief in an unreliable security.

"Another point also deserves the most prominent attention—the greater rapidity with which ships can be built on the Daft principle than on any other, arising mainly from three causes. First, that the large skin plates and the angle-irons, or ribs, may be both accurately punched without the usual to-and-fro labour, and the lifting about of these ponderous masses, and the plates being ready to hand, may be attached as fast as possible to the ribs; secondly, the narrow back-plates being easily and accurately adjusted, can be riveted on with the greatest rapidity, their smaller size allowing much more readiness of adjustment as well as greater facilities of handling; thirdly, all the time and expense of planing and fitting the butt joints are totally and altogether got rid of. To give an illustrative instance of the value of this gain of time in iron shipbuilding we may take the 'Northumberland' as an example. That ship is of 6000 tons dimensions, and to build in the ordinary manner would not, under the utmost efforts, be completed within two years. By using the Daft joints such a ship could be finished in twelve months, and at a pinch even in ten months. And this, too, be it borne in mind, with an increase in absolute strength, much greater rigidity, and no liability to the yawing open of joints, the last, the one greatest difficulty in the structure of iron ships, and a difficulty insuperable with any other material; the difficulty, in fact, which absolutely prohibits the use of wood in armour-clad ships, for no bolts would ever hold tightly together the under-water hull of a wooden ship weighted with a heavy belt of metal armour; nor can wood and iron be used together with any degree of safety or any possibility of endurance. Whether, therefore, Palliser shells, or any other missiles, will penetrate them or not, iron is the only available material for ships, and the time is approaching when not a wooden vessel will be spreading her sails upon the face of the ocean.

"To Mr. Daft belongs the merit of having patiently devoted himself for years to the working out of one great problem—the preservation of iron ships from corrosion and fouling, and in doing this he has incidentally improved the method of building."

### Standard, *December 25th,* 1866.

## THE PRESERVATION OF OUR IRON WAR SHIPS.

"Age improves nothing that we know of but good wine, and even that is not benefited by being too long in bottle. Iron ships are no exception to the general rule of decadence, and as we have already pointed out, some months ago, our most costly magnificent naval defences are not improving in condition. Amongst all the many interesting and instructive topics touched upon in the recent lecture of the Chief Constructor of the Navy at Plymouth not a word fell from him upon one subject of vital importance to the nation—the corrosion of our iron-clad men-of-war. Mr. Reed's objects and intentions are very apparent in his address. He desires evidently to justify his own past course and his own accomplished works against the opposition they have had to encounter, and to indicate the direction in which he wishes his future work to proceed. His comments upon long ships and short ships indicate the first desire; and his advocacy of steam ships without masts, and his expressed preference for wholly iron ships over wooden ships cut down and plated, are evidence of the last. In both cases he has scientific justifications of very valid character. Every subject could not necessarily be handled in one discourse, and what he did do was very much. Still, one can but regret that we did not learn something as to the real amount of deterioration our iron-clad vessels have actually suffered, even before they have all been furnished with their proper armaments of guns. Nothing reliably effective, so far as we can learn, is being done to preserve our iron ships from either corrosion or fouling. And yet there is an effectual means of doing both; but not by the plan we hear is being favoured. It might have been all very well, while nothing better was known, to cover the hulls of iron ships with anti-corrosive paints, glass, stucco, or cement; but these only afford better surfaces even than the iron for the adhesion of the barnacles and weeds; or to apply corrosive sublimate or phosphorus to poison the said barnacles and seaweed that would not be killed, and which lived on and grew and flourished in utter disregard of their strongest virulence. The last official fancy would appear to be to sheath or to "pack," as it is technically termed, the iron ship with wood, and then to cover this over with copper-sheathing; thus in the case of wood-packing (the material selected) making the ship of bigger bulk, and causing the ships practically to drive a vessel six inches larger in every direction than she ought to be, or was intended to be, through the water against so much greater and entirely wasteful resistance, whilst at the same time the ship is left subject through the slightest abrasion against the pier or graze against any other object, the careless driving through of a bolt, or any accidental contact made with a common nail, to the possibility, nay, the very certainty, of accelerated destruction, for the instant galvanic action is set up between the copper and the iron, the destruction of the latter is increased to a most dangerous degree. Nor is the avoidance of absolute contact of metal with metal in the actual construction of the ship a perfect security against such deleterious results, for the merest scraping off of the copper sheathing that would permit the sea water to penetrate the seams of the wood planking beneath, or even the saturation of the wood itself, with salt water, would be equally effective in setting up destructive galvanic action as if the iron hull and the copper sheathing were in the closest contact. Felt, gutta percha, india rubber, are even more treacherous than wood planking, because, being thinner, they are much more liable to abrasion and injury. And yet all these primitive and abortive means are continued in vogue, whilst a more perfect, more simple, less costly, and thoroughly efficacious system is known to exist, and has been proved to possess all the excellences claimed by its inventor, and this too by the very officials who seem afraid to act upon the proof afforded by their own experiments. Iron and wood and iron and copper never did, never can, never will, agree together in a ship. Iron, therefore, must either stand alone and decompose at its own particular rate, or it must be put in combination with some other metal from contact with which it will not suffer. This metal has been proved to be zinc. In August last the second series of trial plates of zinc sheathing attached direct upon the surface of iron skin plates submerged under the orders of the Admiralty, was taken out of the harbour of Portsmouth in such a state of perfect cleanliness, after an immersion of sixteen months' duration, as to leave no reasonable doubt as to the thorough efficacy of the plan. A first series had been previously deposited in the sea at Shoeburyness in 1864 for nearly seven months, by which it was definitely proved, as the second experiments have confirmed, that zinc sheathing stands to iron ships in the exact correspondence with copper upon wooden ones. But although the first series showed that zinc plates of 1-27th inch lost 1-24th of their thickness during their submergence for 28 weeks in contact with the iron, and the second series confirmed this gentle rate of waste, yet the second series, after their 16 months of trial, have been put down again at Portsmouth into the water, either to ascertain to a grain the exact loss of weight of zinc, or for some other minor purpose not at all intelligible to any chemist or electrician. The official manipulations that were made with this very series when they were primarily put down by order of the Admiralty seem perfectly inexplicable. Why, for example, felt saturated with waterproof glue should have been interposed between the iron plates and the zinc in some of the specimens then submerged, may be explained by the Government chemist, but we do not think ever will be by any one else. If anything could have been devised to frustrate the success of Mr. Daft's method, nothing more likely than this could have been conceived; and that it would have prevented success is certain if the metallic contact had not been secured by the driving through of the nails which held on the sheathing, for the zinc system depends for its efficacy upon that very conditionof contact which is ruinous in the case of every other metal. As we know that some of the most important of our national experiments during past years under Whig governments have been totally vitiated by blunders which might have been accidental or might have been intentional, it is not unnatural that competent men should scrutinise closely any interference with inventors' original plans.

"At this particular period, when there is a lull in the progress of our national shipbuilding, and the ministers themselves are reported to be irresolute as to the courses they shall determine upon, it is more than ever desirable that the many undoubtedly valuable novelties which are ready for adoption should neither be overlooked nor set aside. The new process of zinc-sheathing has caused a most important improvement in the way of putting the plates of a ship together, by which greater strength and greater security are attained in combination with a smooth hull. The advantages of a perfectly flush surface are too evident to be dwelt upon; and whatever may be surmised on behalf of wooden vessels, we cannot help feeling the strongest conviction that the days of wood are completely passing away, whether for naval or mercantile purposes. We have long urged the construction of iron ships, and have declared our disbelief in wooden ones. Mr. Reed has well put the case in his remarks on the conversion of our wooden broadside ships into iron-clad turret-ships. Captain Coles's plan, we have no hesitation in saying, can never have proper justice done to it in any other material than iron. No other would do for the turret, no other could be effectually employed in the ship which should carry it. Wood can never be sufficiently bolted together with wood trenails to carry heavy armour plates, and if fastened with metal bolts, the strain by the ponderous plating and heavy weight of the armament is ever tending to tear open the bolt-holes, and thus to damage the hull. Iron, riveted together with a firmness nothing can exceed, must be the material, and as our war-ships are constructed of thicker and more costly plates of metal, the greater the cost and the more the need to take the most effective means for their preservation. What we want, then, particularly to draw attention to in this article is the plan of coppering upon wood-packing, at present in favour with the Admiralty officials, and now being tried, we understand, upon one of the iron ships in the Pembroke Dockyard. The sheathing is, of course, intended also to keep the ship's hull clean, for the cost of docking and scraping our iron vessels is very severe. Of the real value of anti-fouling nostrums in the form of varnishes and paints, there is ample proof. In September, 1864, for example, the 'Achilles' was examined by a professional diver, who found her bottom covered with barnacles and weeds, some of the latter being as much as two feet in length; and at this moment the 'Valiant' is said to have weeds of the length of more than two yards attached to her hull. The conditions of iron vessels coated with Mr. Hay's composition two years ago have evidently not yet been improved up to this hour. Peacock's and other similar compounds have also had sufficient trial; and, setting aside the natural-history aspect of the question, experience sufficiently shows that anti-corrosive varnishes must be sooner or later obliterated from actual use as preventives against that most serious interference with the speed of sea-going ships. Now, copper sheathing over wood packing on an iron ship will be of no more service in preventing fouling than Hay's composition, glass, or stucco, or the absolute surface of the iron itself, as soon as there is any contact between the iron of the ship and the copper of the sheathing, for directly such contact is made, the iron will suffer destruction while the copper sheathing will no longer undergo exfoliation, but, having its surface preserved, will become a permanent basis for the growth of all kinds of weeds. Such metallic contact may be made accidentally in the putting on of the sheathing or packing, or the fixing of the iron holdfasts for the rigging. It may even be established by the overhanging of any ordinary iron chain upon the vessel's side. It is, therefore, evident that no amount of plugging over iron bolt-heads, or any other precautions which may be taken, can even secure the constant insulation of the copper from the iron. If, then, absolute immunity cannot be certainly insured, it is evident that a plan which is open to such numerous casualties cannot, and ought not, to be relied upon. This system of 'packing,' too, increases, as we have pointed out, the size of the ship. Now, as every square foot of midship section takes one nominal horse-power to drive the ship at the rate of ten knots per hour, so will the difference between the packing or extra midship section and the original skin of the ship use up in proportion the steam power.

"If the beam of the vessel be taken at 60 feet, and regarding the curve of the hull under water as 90 feet, then a thickness of packing of four inches all over the bottom will give 30 square feet additional midship-section, and this will absorb steam power to the extent of 30 nominal horses. Thus it will be seen that as this packing is a permanent addition to the size of the ship, so it incurs an everlasting expense for fuel and a constant waste of power, as well as being a serious drawback to the speed, the last being one of the highest essentials for a modern man-of-war. Any diminution in the thickness of the armour plates from corrosion, we need scarcely say will materially diminish the fighting qualities of the ship. The reverse of the estimated gain by additional thickness of plate will take place, and the loss of an inch upon a 9-inch plate would, of course, reduce its resistive strength from the square of 9 to the square of 8, or in other words from 81 to 64.

"Moreover, to this plan we have thought it most important to draw public attention on account of its insidious danger; and it is also desirable to put it in direct comparison with the method of zinc-sheathing. To convey some idea of the principles involved in the two systems, we may point out that when two plates of different metals are brought together in actual contact in salt-water, an electro-chemical element is constituted, and this condition of a single element remains good, whatever may be the size of the plates, the quantity of the electrical force being in direct proportion to the superficial dimensions, that is to say, that the effect produced upon each superficial foot of surface is absolutely alike over the whole plate, one plate being in one kind of electrical condition and the other in the opposite, one metal consequently being preserved whilst the other is perishing. In other words, to express the matter scientifically, zinc being the more oxidisable metal converts the iron into a positive electrode, thus placing it in the like position as copper stands in relation to iron, though not nearly in so strong a degree. Iron, it is well known, is, when in contact with copper, eaten away at a very rapid rate, while the copper is preserved, and fouls at sea with weeds and the customary marine organisms. Zinc in place of copper upon wooden ships has not sufficient exfoliating action to keep a clean service, but slightly coating soon permits of fouling; hence why zinc has fallen into disuse for wooden vessels. But when zinc as sheathing is made to constitute in contact with the iron skin or armour of a ship a single element, then the galvanic action induced hastens the destruction of the zinc in the same ratio as it preserves the iron. This property of the zinc ensures that essential condition of a constant peeling or flaking which always presents a clean metallic surface, and is the only preventive of the fouling of ships. We revert to the insidious nature of the mischief which will go on under the wood packing. This mischief, it is clear, will be totally masked by the 'packing,' and never can be known but by stripping the hull. It is not likely any periodic stripping and re-packing will be encouraged at head-quarters, for the expense would be double that of the original operation of covering the ship; and it is equally certain that without this nothing could be known of the injuries progressing until they made their indications in the interior of the ship, and then all would be too late for remedy.

"The plan of coppering over wood packing is open, therefore, to these serious objections:—It is exceedingly costly as well as difficult to fix the wood packing on to the iron skin of the ship; no thickness of wood will secure immunity from the penetration or permeation of the salt water which constitutes the bath of the galvanic battery formed by the two metals; that while constant insulation cannot be ensured even in the face of the many accidents to which ordinary ships are subjected, the shot-holes and other injuries to which men-of-war are liable will add frightfully to the increase of the causes of such injuries; that copper sheathing, even when separated by wood, felt, or gutta percha from the iron hull is not proof against fouling; and, lastly that the copper is constantly liable to affect the iron hull to the extent that in six weeks an half-inch plate may be entirely eaten through.

"On the other hand, it will never do to leave the iron alone, for as everybody knows, who knows anything at all about iron ships, their corrosion is an item of the most serious consideration."

The following letter appeared in the 'Standard' of the 28th Dec., 1866, from Captain McKillop, who it seems has been directing his attention to the use of zinc for sheathing iron ships.

## PRESERVATION OF IRON SHIPS.

*To the Editor.*

"Sir,—Your admirable article on the preservation of our iron war ships ought to be carefully read by every one who from chance or position has any dealing with, or authority over, iron ships of any class.

"The experiments made with zinc sheathing placed directly on the surface of the iron plates have undoubtedly proved that galvanic action, which precludes the possibility of copper or iron being used within reach of that most insidious action, is made to fulfil the object aimed at (viz., the prevention of encrustation and growth of weed), by the very process which is fatal to the combination of the other metals even when so-called insulation is established, which has over and over again been demonstrated. Having for many years paid much attention to this subject, and examined the bottoms of hundreds of iron ships coated with every imaginable compound, from quicksilver to cow dung, I was much interested in the successful issue of the zinc sheathing, and very much puzzled to know why a counter experiment should be tried with these metals by placing between them the glue and felt as an insulator to kill the very process which had proved so useful. Really one would imagine that the Admiralty chemists' nostrums must of necessity be introduced in some shape or other to mar every attempt to solve the question. The marine glue could not be more out of place if dissolved in the castor oil served out to the Royal Navy.

"Mr. Daft's experiment on stationary plates has undoubtedly been successful, and the wasting or exfoliating process of the zinc has been only sufficient to fulfil the object in view; but this process would be very materially increased by the rapid action of the ship passing through the water. About sixteen months ago I zinc-sheathed the bottom of a floating powder magazine for Messrs. John Hall and Sons, which has ever since been moored below

Gravesend, subject to the action of the tide. This vessel was an old man-of-war, and, of course, has a great quantity of copper in her frame and planking. I was fearful of bad results from the effect the copper might have on the zinc. I therefore chunamed the bottom previous to applying the zinc sheathing, before the chunam had time to harden. The result up to the present is most satisfactory, and in several places where small portions of iron have been covered with the zinc it shows decidedly a cleaner surface, but the zinc is considerably more worn, in one instance right through. I must, however, explain that the water has no doubt access between the iron and the zinc. The average rate of the tide at the spot where the magazine is moored is not more than 2½ knots for a period of nine hours out of the twelve. The thickness of the zinc is 1-16th of an inch. I venture to send you this information, as I think that the subject is one of such vital importance, if we are to go on building iron ships, that every item of information is worth recording,—I am, Sir, &c.,

"Dec. 26. "H. F. McKillop, Capt., R.N."

## ON THE CONSTRUCTION OF IRON SHIPS;

And their Preservation from Corrosion and Fouling by Zinc Sheathing. By S. J. Mackie, Esq. A paper read before the Society of Arts, April 24th, 1867; C. W. Siemens, Esq., F.R.S., C.E., in the chair. (Reprinted from the 'Journal of the Society of Arts.')

"In view of the magnificent total of British iron ships, I need not apologise for taking a survey of the state in which they are kept, and the manner in which they are built, in order to show that they are neither built nor kept as they ought to be, if I can succeed in proving that iron ships might be better built and better kept than ever they have been. Still more shall I be justified in calling attention to these subjects if I can further show that the present depression in the iron shipbuilding trade may undoubtedly be released, and double the amount of tonnage of ships annually constructed hopefully expected for the future of the iron shipbuilders.

"For my own part, I am the more free to speak boldly and unreservedly, in that I am not about to advocate any plan of my own for the remedy of the evils that exist. To my mind there is but one right way of doing everything that has to be done. Men did not build ships when they first began to navigate the seas, but scooped out into canoes the trunks of trees, such as had served them for sitting astride to cross the rivers in their way. Nor did they, when wanting vessels of burthen to carry interchangeable commodities for longer distances, build wooden vessels as large as the East Indiaman of the last century, or as swift as the American clipper of this. So iron shipbuilding, although a modern invention, did not start into existence in perfection, but has gone through various modifications and improvements, until it arrived at its present eminent condition. Progress has still to be made. Far be it from me, however, to deny, or to attempt to diminish the ability and the perseverance of the eminent engineers and practical thinkers who have foreseen and avoided so many difficulties, and have encountered and conquered so many more, nor to undervalue the experience and skill of constructors and skillful workmen. Nor can it be my wish in any way to detract from the deservedly high fame which the English and Scotch iron shipbuilding yards have so far maintained. But there may be a time in the history of iron shipbuilding, as there has been in most other great branches of manufacture and commerce, when those who have got a long way towards perfection, become enamoured with what they have done, and think nothing better to be possible. Such is, to a regretable degree, the present condition of iron shipbuilders. Having done a great deal, there is no disposition to go a step further, although it be but one step further that is required, to make modern shipbuilding as perfect as, in the present condition of science, is possible. The corrosion and fouling of ships may be said to be no business of the shipbuilder; and most men engaged in the trade might possibly admit that cleaning, repairing, docking, and tinkering, constitute a very large proportion of the shipbuilder's business. But herein lies a serious error. Shipowners and merchants are undoubtedly more closely concerned in the preservation of the ship, and in her cleanliness and speed at sea; but if the capacity of keeping a clean hull would create an additional demand for iron ships, is not the means of effectually preventing the fouling of an iron hull in salt water well worthy the attention of the iron shipbuilder?

"Such a means exists, and has been proved undeniably by experiments, and yet there is no disposition to give it practical adoption; a fearful evil exists in the unmechanical butt joint, and yet iron shipbuilders go on planing, and caulking, and fitting at enormous cost, and boast of the beautiful work that sends every iron ship afloat to sea, with the most effectual device for her destruction which the highest scientific knowledge and the most practical ingenuity could conceive. If our commercial shipbuilders will not take the lead, we cannot wonder that the artificers in our naval dockyards are still permitted to pride themselves on the fallacious finish of their butt joints; and while shipowners spend thousands of pounds in docking and cleaning their ships, allow corrosion and decay to have unlimited rule, and besmear the hulls of vessels worth tens of thousands of pounds with red lead, phosphorus, arsenic, and other ineffectual poisons, we cannot express much surprise that to the complaints of naval officers of the fouling and corrosion of their ships, the incasing of our gigantic iron-clads in outer wooden copper-sheathed skins should be the expensive relief afforded by the Admiralty, and that Hay's composition and other so-called anti-corrosive and anti-fouling paints should be in official favour.

"There is but one way of effectually preserving iron ships, which is by sheathing them with zinc in the same way as formerly wooden vessels were sheathed with copper, and as the plan proposed for attaching the zinc plates to the hull has elicited a perfect means of getting rid of the insecure butt joints in the construction of the vessel, as well as rendering it easy to make the skin of the ship flush and fair from top to bottom, and end to end. I have for these reasons proposed to consider the practical construction of iron ships in connection with the main object of this paper, namely, the prevention of the iron hull from corrosion and fouling, by an external sheathing of zinc plates.

"No one of even the slightest experience of iron ships can fail to be aware of the extent of the corrosion and fouling to which they are liable. But of what takes place ordinarily, no notice finds its way into the columns of the newspapers; and it is only of exceptional cases, where size makes the particular vessel remarkable, such as in the case of the 'Great Eastern,' or where the matter commands attention on account of its national importance, as in the case of some of our formidable iron-clads, that any reports come before the general public. The matters of corrosion and fouling are not, however, the less serious that they are permitted to proceed unhindered and on a most gigantic scale in silence.

"We have first to do with corrosion. The corrosion to which iron ships are subjected is the oxidation of the metal. Wooden ships were liable to perforation by sea-worms, and to fouling by sea-weeds and barnacles. After a time it was found that copper attached to a wooden ship's bottom would keep perfectly bright and clean. The use of copper sheathing was first adopted by the Admiralty in 1761, under the prevailing idea that its poisonous influence would be obnoxious to marine vegetation and life, and when H.M.S. 'Alarm' was found clean after a four years' voyage, the success was attributed solely to its poisonous character. The reign of copper at the Admiralty has lasted from that date to the present hour. But copper dare not be put on an iron hull. What was bad before in the extent of the corrosion becomes infinitely worse under the influence of the galvanic action set up by the contact of these two metals.

"In the early days of the sheathing of wooden ships it was found that iron bolts in the timbers, and other objects of that metal in contact with the copper, were eaten away incredibly quickly; and in various accidental ways injuries of a like and very serious nature have repeatedly happened from the contact of copper with the hulls of iron ships. Indeed, it is admitted upon all hands that copper sheathing cannot be applied to iron ships, and that if it were, the total destruction of the hull would be accomplished at the most rapid rate; nevertheless, as copper prevented the fouling of wooden ships, there has been from the commencement of the era of iron ship-building a too general and very fallacious hankering for some method of covering iron ships with copper. Various compositions of india rubber, felt, and other insulating materials have been interposed, in various cases, between the copper and the iron skins of certain vessels; and even at this moment under the persistent tradition of the 'Alarm,' or the commercial influence of Muntz's metal in official quarters, the Admiralty are having some of our huge and costly iron-clads entirely coated below the waterline with a jacket of timber several inches in thickness, in order to insulate that copper sheathing which the wise men of a century since very properly adopted for the preservation of the ships of their day, but which it is surely inexcusable for the men in high places now to put at a dangerous risk upon the hulls of the most costly vessels ever sent upon the seas, when another and cheaper metal, bearing exactly similar relations to the iron which copper did to the wood, could be more simply and more easily applied. It is not possible to ensure the insulation of the copper sheathing from the iron hull of a vessel afloat. Even admitting that the insulation can be perfected when the ship is sent out of dock, the many casualties she is subjected to on her voyage are constantly tending to injure and destroy the insulation. Grazes and rubbings against piers and quays are always liable to make holes in and to strip portions of the sheathing, whilst plates of the covering metal may be peeled in various ways upon the open sea, and, once contact permitted, nature will not be slow in putting galvanic currents destructively in action. Even when an iron ship is actually encased in double planking, the shrinkage of the wood or the opening of the joints by strains of the vessel's motion by permitting the percolation of sea-water will give a connection between the two dissimilar metals of the hull and the sheathing, and the iron of the armour and skin will yield not the less quickly, not the less certainly, not the less dangerously, that it is hidden from the eyesight, or be the less expensive or difficult to repair, that several inches thick of timber have to be removed from the exterior of the ship before the extent of the injuries can be ascertained. One example of the effect of copper on an iron ship is as sufficient for practical illustration as a thousand, if there be a thousand similar facts existent to back it up; and if facts upon this point be desired there would be no risk in engaging to produce a volume. We take one [illegible] years since, that comes readiest to hand. It is from the 'Hereford Times,' of 14th November, 1863. Truth is often spoken of as deep in a well, and rare fragments of honest truth are often to be culled from provincial newspapers:

"'Here is the last little piece of news from the iron squadron. As lately as May in the present year there lay at her moorings off Folly Point, in the Medway, the youngest of these Titans—the "Royal Oak." Of enormous tonnage, giant proportions, and hull that seemed to make the tired ocean groan under her, she was pointed out with pride by yachtsmen and passengers as a "bran-new bulwark of England." Towards the close of May she got under weigh a maiden ship, "ataunto," "spick and span," as handsome as paint and varnish could make her, to join the Channel fleet in its cruise round England. She turned out a capital sea-boat; she showed her heels to the best of the squadron before the wind; and more than once had to lower her topsails to let the laggards in her wake overhaul her. She was "another success," and the Admiralty were as proud of her as the people. Now she comes into port, and what do we hear? That smooth and burnished bottom, coated with "Muntz's metal"—thanks to which she made such fine sailing—has put her *hors de combat* far sooner than fighting could have done. This ship—this Admiralty pet—which has been just four months in commission, is as rotten already as a collier after forty seasons. They have got her into dock, and they find that all along the line between her sheathing and her lower plating, the great and costly iron slabs have perished into something like plumbago. There are holes three quarters of an inch deep, in just that very part of her armour which protects the "wind-and-water line." Where the hooks of the side-ladder have helped the sea-water and the sheathing to do their work, the iron is gone in a deep furrow, and from all the joints of the submerged plates there oozes a black slimy liquor, which is doubtless chloride of iron, and which means that plate and rivet and backing are rotting altogether, inside and out of sight. Into some of the four-and-a-half-inch plates, which were to guard this bran-new vessel, you may poke a penknife blade half way to the handle, in spite of an ingenious band of some sort of metal, not intelligible to those who made the discovery we are describing, the effect of which was to obviate galvanic action. In a word, as we have said, the maiden monster has come into dock rotten from her first trip.'

"This is the account of the effects of copper sheathing three years ago, and yet during the present spring the costly 'Northumberland' has sailed from Chatham for Devonport to be covered with the same destructive metal, and the huge ship, whose launch was so ruinous a labour, may come perhaps, after a brief life of rapid consumption, to an inglorious if not cataclysmal end. How, it will be properly asked, is it proposed to overcome this evil. The corrosion of iron ships may be effectively stayed by the use of zinc sheathing. The zinc sheathing may be put direct upon the iron skin, and the iron will not only not be injured, but it will be preserved. The idea which has been practically worked out by Mr. Daft, in his well-considered plan of zinc sheathing, is this:—If the galvanic action set up in the cell formed by the iron ship and the covering of sheet copper—or Muntz's metal, which is a compound of copper—be destructive of the iron of the vessel, then to use, as a means of preservation, that metal to which iron will stand in the voltaic circuit, as the copper in the former case did to the iron. In other words, if the ship and her sheathing form a voltaic battery, the elements of which stand in such electro-chemical relation to each other that the ship shall be destroyed, then to find out the way to reverse the conditions of that battery, so that the ship shall be preserved. This is done by the substitution of the element zinc for the element copper.

"That we may not appear to be pinning our faith quite upon Mr. Daft's intellectual sleeve, we will quote a few passages from Mr. Lamport's paper, "On Wood and Iron Ships," in vol. iv of the 'Transactions of the Institute of Naval Architects.' He proceeds thus:

"'First.—When chemical decomposition is produced upon two metals in contact, the more oxidizable one becomes electro-positive, and the less oxidizable one electro-negative. The various metals in common use may be arranged in a series, in which those first in order become positive by contact with all those that follow, and negative with those that precede—as zinc, iron, lead, tin, copper, silver, gold, platinum.

"'Secondly.—When any two of the above metals are combined in a fluid capable of acting upon one of them by chemical decomposition, a galvanic current is produced, passing from the more to the less positive metal, which then becomes negative. The energy of the current is in proportion to the vitality of the chemical action, which is confined to the metal which is most electro-positive. The other, becoming negative, is *protected* from the chemical action. For example, if iron and copper be combined in an acid or in sea water, iron, being more electro-positive than copper, is chemically decomposed, or, to use a more common phrase, is "corroded." The galvanic current, passing from the iron or generating metal to the copper as the receiving metal, changes the condition of the latter from a naturally electro-positive condition to one relatively negative. The metal, thus rendered electro-negative by the galvanic current, becomes proof against the action of the fluid as a chemical agent. No decomposition takes place, and it assumes the condition of a "protected" metal, while the more positive one is still more rapidly eaten into and decomposed by the stimulated chemical action. If in place of copper and iron we take iron and zinc, the same process takes place, *reversed,* however, as regards the iron. Zinc, being more positive, is chemically decomposed, and the current passing to the iron renders it negative, and consequently insoluble or "protected." It will, therefore, be observed that it is the chemical action that is deleterious, and that the ensuing galvanic current, by changing the natural condition of the least positive of the metals to that of a negative receiver, protects it from the chemical decomposition to which alone it would have been subjected. Further, the union of three or more metals produces similar results—as with copper, iron, and zinc. The corrosion takes place in the most electro-positive, zinc, to the protection of the other two.

"'Thirdly.—To produce these phenomena actual contact is not necessary, as the fluid itself becomes a medium of combination.

"'Fourthly.—The relative size of the positive and negative metals has no influence upon the direction of the current, which passes always from the most electro-positive metal to the other, irrespective of surface or mass. A small piece of metal, therefore, may absolutely protect a far larger mass of one rendered electro-negative. A considerable preservative effect has been observed when the surface of zinc has been to that of copper as 1 to 1000.'

"The relationship of zinc to iron in a galvanic cell is undoubted; indeed, it may be and was proved by the first voltaic battery recorded, namely, that formed by simply placing two plates of the metals, with their lower edges touching like a V, in a glass of salt and water, or diluted sulphuric acid. This experiment may be performed by any one with pieces of zinc and iron and copper and iron respectively coupled in two ordinary tumblers filled with salt and water. The solution in the one will be colourless, that in the other quickly stained of a deep blood-red hue with the oxide of iron, which will be also deposited in quantity at the bottom of the glass in the condition of ochre. The iron in the other cell will keep for weeks and months perfectly unattacked, whilst the zinc in connection with it will remain bright and clean, from gradually and continually losing a small portion of its volume, a very slight quantity of the white oxide of zinc being deposited in the tumbler.

"Zinc sheathing applied to wooden vessels does not answer; for when zinc is isolated on wood, it becomes its own protector. The zinc oxidizes, and the hard oxide which results soon covers the surface, and exfoliates so slowly and irregularly that fouling takes place to a considerable extent. Copper, on the contrary, when thus isolated on wood, suffers sufficient chemical degradation to present a constantly clean surface. What the zinc requires to compete with the copper for brightness and cleanliness is a little stimulus; and this accelerated action is effectively provided for by the galvanic current set up by its contact with iron. Thus, the one thing needed to make zinc sheathing a success is involved in that desideratum so long necessary for iron ships—the prevention of their corrosion and fouling by the direct application of a metal sheathing. If the expensive sheathing with copper be so repeatedly and persistently attempted, the greater cheapness of zinc cannot be any valid objection to that metal; and this corrosion and fouling can be prevented by zinc sheathing, and that, too, with the additional vital advantage that it will at the same time ensure the most perfect preservation of the ship. We have in zinc exactly what is required—a metal that may be put direct, without any insulating material whatever, upon the bare surface of the iron skin of the ship—that when so placed will form a voltaic cell, the electro-chemical action of which will preserve the iron, while the zinc will only sufficiently and regularly degrade and exfoliate to maintain a clean surface in any waters, at the same time that it is capable of enduring for four or five years without removal.

"I come now to the second point—fouling. This, like corrosion, or dangerous defects of construction, is not the less serious and expensive that it is kept out of the arena of general discussion. It is not to the advantage of shipowners to make any fuss about what they know not how to prevent, or to mention any scheme which has any probability of doing that which they think will seriously diminish, if not entirely ruin, their business. The fouling of Government ships, too, not only involves loss of speed, but more steam-fuel, more food and provisions, longer pay for the crews, and expensive docking and repairs, necessitating the labours of hundreds of men, often for considerable periods of time. I myself saw, a few months since, at one of our principal naval yards, employed for the best part of a day upon one of our large iron-clads, in bringing her into dock and shoring her in position, upwards of three hundred men. But as nobody but the public has to pay the expenses of fouling, and bringing grist as it does to the official mill, it is not at all likely to receive correction so long as that bountiful paymaster, the nation, takes no heed whatever of the matter.

"That the fouling of iron ships is a most serious detriment and a continual exorbitant expense, the very fact that copper sheathing is so persistently attempted, in spite of all obstacles and dangers, is collateral evidence of the very strongest kind; and, indeed, no shipowner or captain of any experience, if put to the test of his veracity, could deny it, however unwilling he might be, from what he probably, but very erroneously, would consider prudential motives, to admit the truth of the assertion. On this point, however, as on others, I intend to take evidence, and from the abundance of witnesses I will now select to bring Mr. Lamport into court. In vol. ix of the 'Transactions of Naval Architects' he admits that the cost of copper is not the reason why iron ships are not sheathed with that metal. At page 289 he says—

"'The next section takes in the doubtful qualities of iron, and the first is that of superior economy of maintenance and reparation. I admit that iron ships do not incur the periodical cost of coppering. But why? Certainly not because the outlay is not needed, but because owners are compelled to forego its admitted advantages. Chemical action forbids the contact of copper or yellow metal sheathing with iron; but I put it to any owner of an iron ship whether he would not willingly pay the cost of coppering to avoid the drawbacks of fouling. If so, can the constrained saving be considered in the light of a gain? Its result is a foul bottom and a lengthened and uncertain voyage; and, as time is money, such saving is anything but economy. But is there no counterbalancing outlay from scraping, painting, or otherwise coating iron ships' bottoms, and is there no loss of material from oxidation of the iron itself to set against the caulking and coppering of wooden ships?

"'By Lloyd's rules, the thickness of the plates for twelve years' iron ships is $\frac{1}{8}$ inch more than those of the six years' grade. The experience of the committee, therefore, points to $\frac{1}{8}$ inch as the waste due to six years' wear and tear. In six years a twelve years' vessel will be liable to be reduced, we may suppose, to the condition of a six years' ship, and a six years' vessel in this period may be supposed to be reduced to a condition to which no class whatever would be assigned. Making every allowance for excess of caution, enough remains to show that the annual depreciation of the iron plates is considerable; and this, added to the cost of frequent docking, scraping, and painting, cannot leave much difference between the annual expense of maintenance of wood and iron ships.'

"Neither is the additional cost of steam-power required to produce an inferior degree of speed in the ship by any means a trifling consideration when the class of the vessel is one of large dimensions and horse-power. Upon this point I will put another reliable witness into the box, again making the selection from the Institute of Naval Architects. At the meeting of 28th February, 1861, Admiral Halsted spoke these words:—'Now I come to another terrible business, and one in which I hope my colleagues in this institution will take a leading part. Here is the "Warrior," with her 1250 nominal horse-power engines, to go fourteen knots an hour. But pray for how long? How many will elapse at sea before the fouling of her bottom will reduce her fourteen knots to twelve, and even below that? As everybody here knows, perhaps better than myself, the fouling of the bottom of iron ships is a question connected, and closely connected, with the nature of the material itself; but I think it is not generally understood that it is not a mere question of the difficulty of preventing the corrosion of the bottoms of iron ships. There are a dozen ways by which actual corrosion of the metal may be prevented, but the misfortune is that all these appliances have the effect of presenting such an enticing surface to marine substances and animals that they carry on their little operations till there is no end of them, and in six months the surface of the bottom of your ship is destroyed, in a great measure, for all purposes of speed. It is wonderful, the money which has been paid away in this country on that account. We possess some 600 iron screw-ships, and there is not one of them but is subjected to this difficulty at least twice a year. And it is not the mere expense of hauling into dock, cleaning the bottom, and re-painting; but it is the number of steam horses that have to be fed to their fullest extent constantly, although the effect produced by their efforts is gradually diminishing. Neither is it that the steam horses cannot take their amount of food; on the contrary, the tendency is rather to overfeed them at such times, so that the reduced speed has no compensating economy, but the whole effect is direct loss. What, then, should prevent the council of such an institution as this submitting that some definite means should be taken to overcome this disreputable fact, which has exposed us to so much public loss up to the present day? There are men of talent in the country who can discover a remedy, or who, at all events, can show us that it cannot be done, and then we may find out some substitute in place of a remedy. I attribute our neglect of this point entirely to the fact of the Government condemnation of iron ships hitherto as being unfit for the purposes of war. Had it not been for that most unjust and impolitic condemnation, I believe a remedy, or a substitute, would, as a great national object, have been provided long ago.'

"Two explanations are necessary to give full effect to the meaning of this speech. In the first place we must bring again to mind that the then apparently incurable disadvantages of the corrosion and fouling of iron ships had so alarmed the Admiralty in 1847 that the sale of the iron ships in our naval service was actually commenced. The persuasive eloquence of the projectors of anti-fouling and anti-corrosive compositions, however, had a happy influence upon the fate of the British iron navy, and the recalling of that desponding fiat is really the only good that ever has been—and in all human probability ever will be—effected by those senseless and fallacious nostrums. In the second place, we should observe that when copper is put upon and in connection with iron in sea-water, not only is the waste of the iron terrifically increased, but the copper itself, on the other hand, becomes totally inoperative and entirely ineffective. It no longer degrades; it is electro-chemically preserved. It no longer maintains, as it would do upon wood, a clean surface; exfoliation no longer takes place, and in proportion as the superficial area of the iron approaches that of the copper so will the latter be more and more coated with thicker and thicker deposits of the carbonate of lime and magnesia abstracted from the sea-water, until the whole of its anti-fouling character is lost and the ship might be but an encrusted rock, covered with luxuriant fields of seaweeds and adherent mollusca floating upside down.

"This fouling is exceedingly expensive at all times, but it would be particularly perilous and vexatious in that of war, to be obliged constantly at short intervals to send our large transport and iron-clad ships into dock for cleaning alone; the retardation of the speed, too, of such vessels whilst at sea is a most serious item, not only in regard to their effectiveness when in pursuit of, but when brought into hostile collision with the enemy. Even in money expenditure it involves a really reprehensible waste. In respect to the mere operation of cleaning, it is notorious that many of our wealthiest shipowners and some of our finest commercial companies prefer to let their vessels run considerably fouled rather than incur too frequently the expensive operations of cleaning and scraping in dock. It may be also said that the merchant shipowner experiences an additional loss in the laying by of his ship, for it is the most active employment of his vessel that produces the most profitable result.

"Again, the immense size of our iron-clads would render delays in getting into dock on account of insufficiency of tides, constant occurrences, while similar delays would also happen in respect to their liberation. Long and dangerous absences would thus be common amongst the vessels of our fleets; and more than possibly at the very time when our utmost naval strength would be wanted, half our vessels might be away, either in dock cleaning, or returning home for that purpose, or on the voyage out again after the operation had been performed. Let us, however, look for a moment, as closely as the little light that has been permitted to be shed on the subject will allow, at the money cost involved by this fouling.

"The 'Diadem,' 800 nominal horse-power, burns sixty tons of coals a day, and does nine knots per ton burnt. Now, if the loss from fouling amounted to one knot per ton burnt, the waste per day of steam fuel would be £14, adding to which the extra cost of wages for the loss of time on a long voyage or a naval cruise, and other items, would bring the loss to something like £25 a day. Again, if the 'Warrior,' 1250 horse-power, and burning not less than 100 tons of coal a day, should lose two knots an hour, or one seventh of her speed, by fouling, the utterly wasted cost of this deterioration of speed—for be it remembered the full quantity of combustion that would give the highest speed with a clean bottom is required to attain with a foul hull this lower rate—would be, supposing English coal were used, £30 a day; and if fuel had to be bought at foreign stations—a most probable and frequent necessity—this expense would range from any increase up to more than double. When to this cost of fuel we add wages and other incidents we shall find that the estimate of £40 a day formed by Admiral Halsted in 1861 of the money value of the loss in this vessel is really within the mark, and entirely within the actual expenditure. With thirty vessels afloat, and assuming the average loss from each as £30 a day, the total waste for the whole fleet would be £900 per diem, or £329,500 a year from this one source of fouling alone.

"In the face of all these evils there is but one hope for the practical application of copper. It is the perfect insulation of the sheathing from the ship. This is the point where Mr. Daft began, and no man has been more successful than he has in this direction.

"In the year 1849, impressed with the importance of preventing iron ships from fouling, and protecting them from corrosion, he made his first step by coating the famous Muntz's metal with an insulating material on one side, in order to prevent galvanic action being set up when such metal was applied to the skin of an iron ship. He succeeded at that time in firmly attaching sheets of pure vulcanised india-rubber to sheets of yellow metal, and when the coated sides of these sheets were placed against the hull, the yellow metal was as perfectly insulated from the iron as it is possible to insulate metals in sea-water.

"The extra care required in the workmanship, and the high price of the copper, were circumstances tending much against the system of insulated copper sheathing, however desirable it might otherwise be. But the fatal objection was that, no matter what might be the care, no matter how perfect the insulation, the connection of the two metallic elements was ever liable to be made by a variety of accidents; indeed, even the overhanging of the anchors, or of an iron chain, might be the medium of setting up destructive galvanic action in a fully sheathed ship.

"But there is a still more costly and even more fallacious attempted avoidance of the difficulty. I mean the faint-hearted compromise between iron and wood. Iron ships are not kept clean at sea;

wooden ships, copper sheathed, are. Therefore, say the compromisers, let us build ships with iron frames and wooden skins, that we may nail the copper on their hulls. Composite ships are the disgrace of the age; they are a standing reproach because they are sneaking confessions of failure and incompetence. Who that knows the value of iron, that has taken action in, or even but watched, its manufacture and its practical treatment in any of its multifarious applications, but feels the same glowing pride in its stalwart strength, its metallic muscle and fibre, its reliability and thorough powers of endurance, as he does in his own birthright to the name of Englishman, and but thinks all the higher of his countrymen that they are unsurpassed as iron-workers.

"Convinced that the system of insulated copper sheathing was and ever must be imperfect, Mr. Daft turned his attention to another metal—zinc, and at the same time set himself to overcome the difficulties which had been experienced in attaching the copper plates to the iron hull. Cement and all sorts of adhesive compounds had turned out complete failures, and nothing but the old plan of nailing the sheathing on, as it was done upon wooden ships, seemed likely to answer.

"To make an iron ship, and then to cover it over thickly with wood—to put, in fact, the iron ship inside of a wooden one—seemed to him, as it must still do to every competent person, a most undesirable and unscientific procedure. Having by his experiments convinced himself thoroughly of the value of zinc sheathing, he devised the most simple and admirable plan for the firm attachment of the plates that could possibly be desired, and in doing this he has made the most important improvement in the construction of the iron ship itself. The butt joint was the weak part of the ship; Mr. Daft wanted a groove round every one of the skin plates which he could fill with wood, as the medium to which to nail his zinc sheathing plates, and in getting his groove he got rid of the butt joint. But of this, hereafter; for the present we have to deal with zinc.

"With zinc sheathing we have the following advantages:—It is one third the price of copper or yellow metal; it requires no insulating material, nor anything whatever interposed between it and the iron skin of the ship; it electro-chemically protects the iron, and is itself degraded and imperceptibly peeled away by the same electro-chemical action; it keeps perfectly bright and clean, and is as durable as copper or Muntz's metal.

"Of these assertions some proof will naturally and properly be asked. Cabinet experiments might be possibly deemed not sufficiently practical upon such an occasion as the present, however interesting and instructive. I bring forward, therefore, the results of actual trials of the system made by the Government.

"After proving the value of zinc as a sheathing for iron in sea-water, in conjunction with the 'Special Committee on Iron,' in 1863 and 1864, Mr. Daft received instructions from the Lords Commissioners of the Admiralty, on the 18th February, 1865, to visit Portsmouth Yard, in order to see that certain experiments with two plates upon his plan were satisfactorily made for testing the efficacy of zinc sheathing for iron ships.

"Two plates were made up of ¾ inch plating, with ¾ straps at the back or inside, so as to represent the actual plating of a vessel of some 3000 or 4000 tons, and grooves, according to Mr. Daft's patent, were left, of ¾ inch wide, between the edges of the plates; these grooves were subsequently filled in with teak strips, and the surface made fair and flush. The plates were encased in teak frames and backs, made waterproof, so that they (the plates) should have their faces or outsides only exposed, as in the case of an actual vessel. Mr. Daft's original intention was to nail on the zinc sheathing directly against the bare iron, in order that the contact between the zinc and iron should be perfect, and that the necessary amount of electro-galvanic action should be set up when the plates were lowered into the water to keep the zinc exfoliating or peeling away at a rate which would keep them clean and bright; but by instruction the iron was coated all over with a composition in fashionable use in Her Majesty's dockyards—Mr. Hay's glue—and contact had therefore to be established by using nails for fastening on the sheathing, long enough to go through the teak-caulking in the grooves, and to turn against the iron at the back of it. A few *iron* nails—common clouts—were introduced, in order to establish firmer and more enduring contact, and to prove that they might be used, if not to advantage, certainly without detriment to the work.

"The unfortunate interposition of an insulating substance between the zinc and the iron would have rendered the former liable, but for the action established by the long nails, to foul to a certain extent. In fact, the insulation directed would, if it had not been practically subverted by this means, have produced in the experiment results parallel with the case when zinc is used for sheathing wooden vessels. This test was a source of anxiety to Mr. Daft, which was only dispelled when, on the 12th October, 1865, the plates were raised for preliminary examination (as they were to be twelve months under water for the trial). At this examination, after six months' immersion, they were found perfectly clean, though not bright, as would have been the case had the chemical action not been checked by insulation. The zinc had not wasted enough. An ounce per foot per annum—the rate at which it had been disappearing—was not sufficient to ensure a bright surface, a bright metallic surface being that of all others the most to be desired for obtaining speed in iron ships or wooden vessels. This fact, that the zinc could be kept perfectly bright, having been thoroughly established previously by Mr. Daft, induced him to cause a third experiment to be made at Portsmouth.

"At the end of the year of trial a correspondence took place between Mr. Daft and the Admiralty as to raising again the two plates; but, as summer was approaching, it was suggested by the Admiralty that they had better remain three months longer. They were thus doomed to go through another season for the rapid growth of weeds and barnacles, which, as any naturalist will quickly perceive, was subjecting them practically to another year's trial, by including two spawning seasons of the barnacles and molluscous animals, and two seasons of the fertilising periods of the seaweeds, giving the plates, in fact, a double chance of fouling. This suggestion was, however, readily agreed to by the inventor; and when they were taken up for the inspection of the Lords Commissioners of the Admiralty, on the 12th of August, they were found still in a state of the most perfect cleanliness, though, as before, not bright. About the frame, and on the iron chains in which the plates were swung, were immense quantities of barnacles and weeds, but not a vestige on the plates. Mr. Daft then suggested that one or both plates should be stripped, and everything—zinc, nails, teak, iron, &c.—thoroughly overhauled, and an accurate account taken of the loss of the zinc; and this was, he believes, with respect to one plate, accordingly done. Not that the 'authorities' have furnished him with particulars, but, having asked for that favour, he is in hopes of getting them. However, it may be asserted, without fear of contradiction, that the zinc had lost only at the rate of exactly one ounce per foot per annum. It would be better that it should lose double that quantity.

"One ounce per foot per annum is not much more than zinc sheathing loses on wooden ships, where a very feeble galvanic action indeed exists, and possibly at times none at all, when fouling more or less occurs. Not, as we have already stated, that fouling is peculiar to zinc alone, for other sheathings—copper and yellow metal—foul to the same extent as iron or zinc, or any other metal, when their condition is made negative in an electro-chemical sense. If, for example, contact with iron and copper and yellow metal be made in sea-water, then yellow metal and copper will foul rapidly at the expense of the certain destruction of the iron—the positive metal. Mr. Daft thinks that in order to wear out the old wooden ships with as little expense as possible, and yet keep them useful and safe as long as they could be, it would be wise to use iron nails and zinc sheathing, for the zinc would preserve the iron fastenings about the vessels, and the clouts (iron nails) in the sheathing would hold the zinc on longer than zinc nails, and materially aid in keeping it clean by increasing its exfoliating qualities. Zinc for wooden ships under this treatment would become equal to copper or yellow metal for cleanliness, would last quite as long, and would cost no more than one third the price.

"To ensure a thoroughly clean surface, the 'peeling away' should go on at a rate of not less than 2 oz. per square foot per annum. At that rate it is kept absolutely bright, and may be still further increased to 2½ oz. by leaving certain parts of the hull unsheathed —for example, the keel, stem and stern posts, &c.—for by exposing a greater proportion of iron than zinc (within certain limits) the zinc is more rapidly destroyed, while, as I have in another place shown, the uncoated iron is, notwithstanding the immediate absence of zinc, kept free from fouling for some reason that at present I fail to perceive.

"An exceedingly useful feature is the power that is possessed within certain limits of thus modifying the electro-chemical action on the zinc. There is a definite relationship between the extents of the surfaces of the iron and the zinc, and the rate of the exfoliation is in exact proportion to the areas of the two metals. The electro-chemical action can therefore be modified, accelerated, or retarded, according to requirement, by the proportion of the ship that is sheathed, or by internal plates in connection with the bilge-water. Thus, sheath one quarter of the iron, you give half the superficies of zinc to iron, and in this state, when immersed, the destruction of the zinc is at a medium point, and the iron is perfectly protected. Now reduce the sheathing to $\frac{1}{8}$th = $\frac{1}{4}$th of the surface, and you increase the destruction of the zinc, but the iron is still fully protected; still further reduce the zinc to say $\frac{1}{16}$th = $\frac{1}{8}$th the surface of iron, and you arrive at the maximum destruction of zinc. Go further in this direction, and you do not increase the destruction of zinc, but you enfeeble the protection of the iron.

"Entirely cover a surface of iron with zinc; you then have two to one of iron; in this state the exfoliation of zinc is feeble, but quite enough to keep it bright in sea-waters. The iron when completely covered is, of course, fully protected by the electro-galvanic action exerted upon the zinc, and, in fact, a singular proof of this has just occurred in the Admiralty specimens inspected by the Lords at Portsmouth. A plate, grooved and caulked with teak, about 2 ft. 1 in. by 1 ft. 4 in., was partly plated with zinc, in order to try the comparative results, and a margin of bare iron, about 3 in. wide, was left around the sheet of zinc. This specimen had been under water about ten months; the zinc was beautifully bright and clean; the margin of iron was only coated with a little slime, which, upon being rubbed off by the finger, discovered a bright clean surface; the wood frame about this specimen, which had been fixed to it for lowering it into the water, was an enormous mass of polypi, barnacles, and weed, thus proving that the zinc had a protecting effect to some distance beyond the actual surface covered by it.

"The moment we come, with a proper knowledge of the natural history of the subject, to investigate the nature and character of fouling, and what should properly be its most perfect prevention, we come decisively to the unalterable conviction that all anti-corrosive and anti-fouling paints can never be any more than the merest nostrums. Barnacles do not feed with their feet; oysters do not imbibe nutriment through their shells; mussels derive no vital sustenance through the cords of the byssus by which they moor themselves. Seaweeds are not like land plants, which take up their supporting fluids by the fibres of their roots. The 'root' of a seaweed is no more than the mere disc of attachment, the leather 'sucker' which holds it to the rock or to the side of the ship. The idea, therefore, of poisonous compounds for painting a ship, with the view to killing the barnacles, shell-fish, and seaweed, is to the mind of a naturalist much on a par with a project for poisoning a man through the sole of his boot. The individual who should propose to smear the ground with phosphorus and arsenic to destroy an invading enemy would be sent to Bedlam, but the quack who offers arsenical and phosphoric soaps for ships' bottoms sells his wares and injures no one but his customers.

"There is another view to be taken of the natural history of shell-fish and seaweeds. All the things that attach themselves to a floating ship only stick to it, and the proper cure therefore is never to leave them any surface to stick to. Why copper on a wooden ship keeps clean is because it never has a permanent surface, and it is evident nothing can long adhere to a surface that is always dissolving away. Now, it is only in the young state that either marine organisms or vegetation have the power of attachment to foreign bodies. Pull an oyster from its bed, or a seaweed from its rock, and neither is ever a fixture anywhere again. If, then, the minute young only of shell-fish and the minute seeds only of seaweeds possess either free or involuntary locomotion, it is clear they can only adhere to very minute portions of any solid surface, and, therefore, as the extent of their adherence is not larger than the exposed surface of a metallic particle, it is evident that the exfoliation of that particle will carry away with it the minute organism attached; and it is also as evident that as that organism has only once in its life the power of attaching itself, its capacity of individually contributing to the fouling of any ship is gone for ever. The exfoliation of the metal of a ship must, therefore, be constantly going on. The voyages which the vessel undertakes will take her from winter in one latitude to spring time and spawning and seeding season in another; and wherever and whenever the myriads of young mollusca, cirrhipedes, serpulæ, corallines, bryozoa, and teredines, swarm in the sea, then and there will they seize upon every bit of the vessel within their reach, and so long as the surface of the hull remains will go on growing and prospering to the serious detriment of the progress of the ship. It is equally evident, under this aspect of the case, that fouling can never be prevented by any vitreous or glazed substances attached to the hulls of ships. However smooth or polished, however slippery any absolute solid permanent surface may be supposed to be, young barnacles, oysters, mussels, take too good a hold upon it, and the little floating seeds of seaweeds stick too close to it ever to slip off, and can only be got quit of by being 'slipped away with' by the flaking of the surface itself.

"Needless as any proof on this subject would thus appear to be, it is, nevertheless, imperative to put in an example or two of actual results of anti-fouling paints. These results are of two distinct characters. One, the effects produced in respect to the fouling of the hull; the other, the effects produced upon the iron, for many of these anti-fouling and anti-corrosive compositions are by no means innocuous to the constructive material of the ship. I really am very sorry to select 'Hay's anti-fouling paint' as an illustration, because Mr. Hay is the Admiralty chemist, and his 'composition' is under the immediate patronage of the Admiralty. But I take it because it should be, from the recognition it has received, presumably the best of its class; and because, if I did not take it, I should hereafter most probably be accused of having insidiously picked some inferior example, designedly leaving out the very one I ought to have brought forward in justice to the anti-fouling painters. I quote from the 'Times' of 18th November, 1864—not an unfriendly organ towards the dockyard officials:

"'Notwithstanding the numerous descriptions of what are termed "anti-fouling" mixtures, which have been submitted to the Admiralty, no discovery appears as yet to have been made of a preparation for effectually preventing the accumulations of animal and vegetable matter over the hulls of iron vessels.

"'Although the bottom of the iron frigate "Achilles" was coated over before her launch with the "anti-fouling" composition of Mr. Hay, the Admiralty chemist, so foul had the bottom of this vessel become while lying in Chatham harbour, preparing for sea, that in the run from Chatham to Devonport her speed fell off more than three knots an hour from her steaming rate on the occasion of her official trip at the Maplin Sands.

"'When docked at Devonport the bottom of the "Achilles" was not only foul, but many of the plates were left completely bare of composition, while corrosion had in many cases eaten away the plating to the depth of from $\frac{1}{16}$th to $\frac{1}{10}$th of an inch.'

"I can add my own testimony, having seen the 'Valiant' put into dock a short time ago, after sixteen months in harbour, that the condition of Mr. Hay's composition, or of the iron vessels coated with it, has been in nowise improved; nor can I conscientiously say one single word in favour of any other of the 'compositions,' anti-fouling or anti-corrosive, with which various portions of that noble iron-clad was besmeared. Mr. Hay's compound has a basis of copper, and the hull of the 'Valiant' was deeply eaten into by the galvanic action, as well as thickly and totally encrusted with a bronze-coloured oxide. It certainly was not so foul as some other portions of the ship, but it would not have been even in a semi-clean state if it had not been 'hogged' by some new patented scraping machine before the ship came into basin.

"Doubtless I should find I had left a hole in the armour of my argument if I omitted to say a few words upon the other metallic paints in which other metal bases are used—as red lead, quicksilver, and zinc. I assert of all such, without fear of defeat—contradiction on all points I know I may expect—that no paint having the oxide or other salt of any metal can possibly be of any use in the prevention of fouling; and not even if the absolute metal itself in a pulverized state could be mixed in with the oil, varnish, or other medium, would such a paint have any preventive influence. Take zinc itself in fine powder, for example; it would be utterly useless, because each particle of the metal being encased in and insulated by the medium of the paint, galvanic action would be stayed, and there would be no exfoliation of the surface—the sole means of avoiding marine foulness. In the cases of red lead, mercury, plumbago, and antimony, if they have any effect at all, it will not be upon the barnacles and sea-weed, but upon the iron hull; and this any action they may exhibit will not tend to improve the condition of. Some owners use merely a thick coating of simple grease for ships going on distant voyages, and so long as the friction of the water can carry off the weeds when they have acquired a certain size, it may possibly do so as long as the grease lasts; but what then? Fouling of the iron hull of course sets in. How far efficacious this plan may be, in even its best circumstances, I know not, but this I do know, that one large house that has wisely eschewed anti-fouling compositions, and uses this less hurtful means, pays probably the largest sums, and certainly takes more care and pains in docking, scraping, and painting its ships than any other in the port of London. And it is well repaid for this expenditure. Paints of all kinds must be peculiarly liable to be rubbed and scraped off, and of course the iron hull over such portions would then be completely unprotected, and fouling and corrosion would go on as it pleased.

"I have been thus severe, but no more so than is deserved, upon paints and coating compositions of all kinds, because one of the antagonisms zinc sheathing has to encounter is the notion entertained by sailors and owners, and particularly the former, that they should have 'something to paint the ship with.' A sailor naturally likes to paint his ship, for much the same reason as a child his toy-boat; and owners abide by paint for their iron ships because they don't know what else on earth to do with them; and because to sheath them with copper is highly dangerous, as well as expensive.

"Another antagonism to the trial of zinc sheathing amongst merchant shipowners is the objection they have to having anything done to the skin-plates for the purpose of securing the sheathing. Mr. Daft effectually secured his insulated copper by drilling holes partly into the thickness of the skin-plate, and plugging them with wood or ebonite, and then driving the nails which secured the sheathing into these plugs. For myself, I see no objection whatever to this plan, but shipowners are excessively timid about the slightest mechanical operations, although they have no suspicion or fear of chemical action being painted all over their ships.

"We have so far taken a broad survey of the nature, character, and action of zinc sheathing, and are brought now to a consideration of the best way of putting it on.

"It appears, then, that in order to perfectly protect iron hulls for an indefinite period from corrosion—in fact, to preserve their thickness in its full and original integrity, until every other part of the vessel is thoroughly worn out—we have only to plate the bottoms in a simpler, cheaper, and safer method than has ever before been done. This Mr. Daft has accomplished by making all the joints lap joints, and entirely avoiding butt joints and their costly and evil consequences. To make the laps fair and flush, and perfectly water-tight, they are, in addition to the ordinary punched caulking (if that be thought desirable), caulked with properly prepared strips of compressed teak, and then the zinc sheathing is most firmly secured by nailing on the sheets to the teak in the grooving in the ordinary manner of fastening copper sheathing on wooden vessels, the zinc being, at one and the same time, the complete preserver of the iron hull and the essential metal for keeping the bottom perfectly clean for a number of years proportionate to the thickness of the sheathing used. If, for example, a sheathing of one twentieth of an inch thick be used—as a good stout sheathing fit for a vessel of 3000 to 5000 tons would be—it would weigh thirty ounces to the square foot, and assuming a loss of two ounces per annum, and that when it was reduced to half its thickness re-sheathing would be required, we have at least seven years of a clean and safe bottom, without the least anxiety about it as to fouling or corrosion. It is important in its place to determine the size and shape and appointments of our new iron fleet, but it seems out of place to do anything before the very base and foundation of the superstructure be settled. If our magnificent broadsides, cupolas, monitors, or whatever we may come to, be dependent upon any description of paints or compositions, and be really wanted on service, they must all go to ruin by corrosion before the end of a commission, or come into dock every six months to have their hulls cleaned and re-painted, to say nothing of the diminished value of a vessel which begins to foul from the day she leaves port, and gradually but surely gets worse, until her boasted speed is reduced to two thirds, and even to half its original rate.

"Almost all iron ships as now built present longitudinal rows of plates, alternately projecting and receding—'in-and-out strakes,' as they are called by shipbuilders. In these strakes the joints are of two kinds—one made by the overlapping of the edge of one plate upon another, and called the lap joint; in the other, the edges of the plates are planed smooth, and the ends brought close to each other, the joint being made good by the riveting of the ends of both plates to a common back-strap. That is termed a butt joint, because the two ends merely 'abut' against each other. The lap joint is in every way by far the stronger; the rivets penetrating both plates, and, being driven in red hot, by their shrinkage exert such power that the lap joint, if properly made, is absolutely stronger than the plates themselves. But such is not, and never can be, the condition of the butt joint. That is a form of joint that in its essential character is the very weakest possible. It is really of the nature of a plate half cut through; and a very correct general notion of its condition may be given by comparing it to a plank sawn across to the half of its thickness. Because a saw-cut was formed of three pieces, a plank cut quite through and a back piece, it would not cease to be a saw-cut; and just so, although the butt joint is formed of the two ends of two plates and a back-strap, the line of particles in that back-strap facing the seam between the ends of the plates will be that portion of the metal which will have to endure all the strain brought upon the joint. A saw-cut weakens a plank more than the proportion of its depth to the original thickness, because there is a leverage of the substance of the wood, brought to bear during any strain, that opens the cut upon the front line of particles of the uncut remainder of the plank, and which is thus liable to be rent asunder, and in this way the crack is easily continued. The back-strap of a butt joint is always in the condition of the remainder of a saw-cut plank; and, as such butt joints are used for the vertical joints of the strakes, there are many hundreds of such butt joints in a ship always liable to be strained open and split, and that too, it may be, all over the ship. When vessels strain across ocean waves, the butt joints are exceedingly likely to give way; and many iron vessels have gone down from no other cause than the opening of their butt joints. When iron vessels are strained, it is usually along the lines of butt joints that they part asunder; and, in brief, all the accidents that arise from the defects of, or strain upon, the fabric may be set down, with hardly an exception, to the giving way of the butt joints. No one ever heard, that I know of, of lap joints, where the workmanship was good, giving way; but the iron-shipbuilder prides himself upon the finish of his butt joints, and thus in the very pride of his craft confesses the inherent deficiency of the butt joint. Why should he pride himself upon the extra care and finish bestowed upon it if it were as good as the less-cared-for lap joint; and why should he use the lap joint for his horizontal strakes, and make an uneven irregular hull for the ship, when with the butt joint he could make a fair and flush hull if the butt joints were not inherently worse? He certainly would reject the lap joint if it were not for its superior strength. But the weakest part of a ship is its actual strength, and therefore, as the lap joints are its strongest parts, the butt joints detract from the entire stamina of the vessel. Now, in putting the groove round each plate for his infilling of teak, Mr. Daft uses a plan which entirely gets rid of the defective butt joint altogether out of the ship. By putting the plates an inch apart, he takes the joint out of the category of a saw-cut, and by putting a narrow plate of the same thickness as the skin of the ship at the back of the joint he virtually reduces the in-strake from three feet wide to one inch in width. It is still, however, of the nature of a strake; and the metal of the inner plate, when any strain comes upon it, has sufficient extent of surface to bend into an arch, and no single line of particles having to bear more than its proper share of the strain, there is no longer any liability for the metal to be pulled apart or to crack. The extravagant expense of planing the ends of the iron skin-plates is entirely done away with, the edges of the plates being left just as they come away from the shears, and the teak, carefully dried, compressed, and forced tightly in, securely caulks the joint, and makes the entire surface of the hull perfectly fair and flush. The whole construction of the ship under this process will be quicker and cheaper than ever; there will be no inequalities in the rigidity or strength of different portions; no sharp edges to encourage the commencement of oxidation and fouling, and there will be the most suitable means of nailing on a metal sheathing to protect the iron hull from corrosion from salt water when afloat. What Mr. Daft has done really is to have turned the insecure butt joint into double lap joints; the result is mechanically right, and the wonder is that it was not seized upon by every builder the moment it was devised. But strong is the force of habit: and it is a common failing of men to cherish most highly that which has given them the most trouble. Troublesome things, however, like troublesome people, are seldom good for much.

"Both subjects, the construction of iron ships, and zinc sheathing, permit a great deal more to be said about them; but a paper for a society's evening meeting cannot go to the extent of a volume. I will, therefore, only add that, as wooden ships are still built in large numbers for foreign voyages of long duration, solely because of the fouling of iron ones, I do believe the adoption of Mr. Daft's process of zinc sheathing, by enabling iron ships to undertake voyages of any length of time in a perfectly clean state, will throw into the iron-shipbuilding trade all the orders that would otherwise go, as now and heretofore, to the builders in primæval wood. Iron ships are incomparably stronger and are much lighter than wooden ships, and can be made on finer lines.

"I now ask full discussion on these subjects, in which I have become interested, in the firm conviction of their correctness and importance, and which, for those reasons, I wish to see put to practical trial by shipbuilders and shipowners."

### *Discussion.*

"Mr. Haddan said he was afraid that Mr. Mackie had sought to prove too much, for this reason—that if all he had stated was correct, iron vessels would wear four or five times as long as they do now, and, consequently, the trade of shipbuilding would be reduced to the extent of four fifths, unless a very greatly increased demand for ships arose. He had himself tried to induce people to make important changes in materials for manufacturing purposes. Some years ago he brought forward a plan for building railway carriages with papier-mâché, which would last twenty years; but on introducing the subject to a carriage builder, he would not entertain it for a moment, because, he said, he did not want carriages to last twenty years, for, if they did, what would become of his trade? But, he added, if he could show him a plan by which they would last only a year, he would take it up. He could hardly suppose that the Admiralty authorities of the country were influenced by these feelings, but he thought that they were in the habit of waiting to see what other countries did; and he believed if Mr. Mackie or Mr. Daft could induce the Emperor of the French to try this plan of zinc sheathing on one of his vessels, and it succeeded, our Government would adopt it instantly. He considered this invention a very important one. He was not a shipbuilder, but understanding something of the properties of iron, and hearing the explanation of the system which had been given this evening, he believed it to be a sound one, and he hoped public pressure would be brought to bear upon the Government to give it a fair trial.

"Mr. G. B. GALLOWAY submitted that the question before the meeting was one of paramount national importance. He would refer to a statement which was made in this room at the meeting of the Institute of Naval Architects in 1865, by Sir John D. Hay, one of the present Lords of the Admiralty, who said that, unless some mode were discovered to preserve the bottoms of iron ships, in a short time we should have no iron navy in existence. He (Mr. Galloway) begged to ask the author of the paper at what dates the tests of this invention had been made under the auspices of the Admiralty authorities?

"Mr. MACKIE replied in 1863 and 1864, at Shoeburyness, and from 1865 up to the present time at Portsmouth.

"Mr. GALLOWAY said the quotation from the 'Times' which had been read lamented that no discovery had been made for the preservation of the bottoms of iron ships, while they had the fact before them that these tests were made prior to the date of that article, when proofs had been afforded that this system was most certainly a valuable one. It was a national disgrace that, in the face of this invention, there should still be going on the enormous waste of public money resulting from the fouling of the bottoms of our iron navy.

"Mr. C. F. T. YOUNG said he had listened with great satisfaction to Mr. Mackie's paper. He had had many opportunities of observing the evils which resulted from the fouling of ships' bottoms, the effects of which had been in no way exaggerated by Mr. Mackie. The idea was still held that the copper bottom of a vessel kept clean because it was of itself a poisonous material. However poisonous it might be in itself, it had not a destructive effect upon the organisms which infested the bottoms of ships. The rapidity with which this fouling proceeded was hardly to be credited. The Southampton pilot boats, during the summer months, had to lie ashore every fortnight to clean off the fouling, and the St. Mawes pilots had to do the same. It was stated that the 'Gloire' and other French iron-clads had, on an average, passed fifty-five days each in dock during a period of little over fourteen months only to remove the fouling. With regard to the cost of keeping ships' bottoms clean, it was stated that the P. and O. Company spent £70,000 annually simply for keeping their ships' bottoms clean. One iron ship of 800 tons, which had been eight months in a warm latitude, had thirty cart loads of barnacles taken off her bottom, an estimated weight of twenty-eight tons. It was calculated that our iron-clads had each to spend fourteen days every six months in dock to remove the fouling, although they were frequently hogged. The iron steamer 'Megæra' was found to incur an increased cost in running of £23 per day through having a foul bottom, the same amount of fuel only producing seven knots an hour in place of ten. It had been proved, from careful tests made with the Dublin and Holyhead mail steam-packets, which were very fast boats, that, after they had been out of dock two months, their speed uniformly fell off from half a mile to one mile per hour from fouling only. With regard to the alleged poisonous effects of copper, any one who had seen the oysters on the coast of Cornwall knew that they were perfectly green coloured from being impregnated with copper, so that it was impossible to eat them, and yet they lived and thrived. Eighty tons of barnacles were taken off the copper bottom of an old wooden ship which was broken up some years since. About a year and a half ago an experiment was tried, at the instance of the Scottish Shipbuilders' Association, as to the powers and advantages of the so-called poisoning process. The four quarters of an iron plate were each thickly coated with the most poisonous compounds that could be found—arsenic, corrosive sublimate, &c.—and the plate was immersed in sea-water for some months. When taken up it was found to be in the most foul condition possible, and it so happened that the largest barnacle of all had placed itself at the junction of all the four compounds. It would hardly be believed that there were persons who, even at the present day, would deny the existence of galvanic action; but it would seem that this idea was held more generally than would at first be supposed, when we found the use of yellow metal and copper on iron ships still adhered to in the navy. Mr. Young called the attention of the meeting to a piece of iron plate on the table, which had been experimented on, by covering it with Muntz's yellow metal, insulated from the iron by vulcanised india-rubber and felt; and although the edges were protected so that no water could get between the copper and the iron, yet, after having been immersed for several months, the iron was found to be very much eaten away, owing to the galvanic action. The 'Achilles,' when docked at Plymouth, was found to have her plates eaten in from $\frac{1}{16}$th to $\frac{1}{10}$th of an inch deep, and was very foul. Numerous other instances were given. The 'Royal Oak' iron-clad, with a coppered bottom on a wood sheathing, was found to have had her plates eaten by corrosion to the depth of three eighths of an inch in less than eight months. With regard to the employment of poisonous paints, if the barnacles held on by their mouths there might be some sense in using them, but they hold on by their feet instead. Some of the barnacles taken off a plate painted with arsenic were boiled and given to a cat, and the animal died with all the symptoms of arsenical poisoning, while the barnacles themselves remained wholly unaffected by the compound.

"Mr. Botly said they were much indebted to Mr. Mackie for the paper he had read; it was a matter of the greatest importance, not only to the Society, but to the country at large, that such a subject should have been brought forward. The paper treated of two great improvements in the construction of iron ships, viz. the lap joint for the plates, and the zinc sheathing as a protection against fouling. Both these matters were of the utmost importance, and deserved careful consideration.

"Mr. Campin asked whether the action of the zinc sheathing, in keeping off the barnacles, was supposed to be due to the electric current, or merely to the wearing away of the surface of the zinc.

"The Chairman said the paper sufficiently explained that it was the slipping away of the surface of the zinc from the feet of the barnacles, by exfoliation of the metal, which kept the bottom clean.

"Mr. Blackie inquired whether the zinc to be used for sheathing was prepared in any special manner different from the ordinary mode of manufacture.

"Mr. Mackie replied that the zinc was prepared in the usual way. It might, however, be found desirable to adopt some annealing process, to get rid of any extreme rigidity of the metal.

"Mr. Blackie remarked that those who had zinc water-cisterns would probably have observed that an incrustation took place on the zinc. He would like to know whether the action of fresh water on zinc was different to that of sea-water.

"Mr. Mackie replied that fresh water would produce a deposit on the zinc by evaporation; but when iron was present, salt water set up a galvanic action between the two metals.

"Mr. Blackie then called attention to the question of the expansion and contraction of zinc as compared with iron, and expressed his opinion that there was great liability of the zinc cracking. He would also like to be informed as to what would be the cost of plating a ship with zinc as compared with copper, the cost of cleaning being added. The cost of sheathing a vessel's bottom with zinc, he apprehended, would be considerable, and it appeared it would require to be renewed, owing to the wasting of the metal, in the course of a few years. The question, therefore, arose, whether the cost would not be greater than that of docking the ship occasionally, and clearing off the fouling.

"Mr. E. J. Reed (Chief Constructor of the Navy) said the paper appeared to be a very able and interesting one, but one or two things had been said in it which he could not allow to pass without notice. He thought the theory enunciated as to the weakness of the butt joint, viz. that there was liability of the joint breaking at the line where the plates touched, was erroneous; in practice it was found that fracture, when it did occur, took place in the line of rivets. He did not say the butt joints never broke at the line of junction; but, when they did so, it arose from the fibre of the iron in the butt strap being put across, instead of lengthwise. His opinion was that, with ordinary good iron shipbuilding work, when pains were taken to put the fibre of the iron in the direction of the fibre of the plate, and with a slight increase of thickness of the butt-strap, it was not found that the butt broke in the way suggested in the paper. With regard to the subject of fouling, he might say that to his certain knowledge it had been a matter of most anxious consideration, and also of experiment, by the Admiralty ever since the introduction of iron ships into the navy. For two or three years the late Board of Admiralty and the Controller of the Navy sanctioned a large number of experiments with anti-fouling and other compounds, but with, he was bound to say, no very satisfactory results; indeed, there seemed little promise of anti-fouling compounds doing all that was desirable in keeping iron ships' bottoms clean. He thought much was yet to be done in that direction, particularly by getting rid of the irregularities of the surface of the immersed bottom, and making it perfectly flush and even, so that it could be easily cleaned by being brushed while afloat, as was done in former times with wooden ships. But still he thought any advantage thus obtained would be very inferior to an arrangement which would secure a permanently clean bottom. The system described in the paper was certainly entitled to great consideration, in spite of any little difficulties that might at first appear to belong to it. For instance, at first there appeared to be considerable difficulty in caulking the joints, but his own feeling was that in a matter of this magnitude and importance mere mechanical difficulties of this kind would soon be got over. We had already encountered, and were still encountering, very much larger difficulties, and we could not now afford to be deterred by trifles from adopting any real improvements. He might, however, say that no experiments had yet been made with this invention which would carry complete conviction to the Government. The minds of all those persons who were responsible must first be fully satisfied. For his own part he did not attach much value to the experiments at Shoeburyness; moreover, they were on too small a scale to warrant the formation of any conclusion upon them. In many instances, no doubt, when the copper sheathing had been placed in contact with the iron, a most destructive galvanic action had taken place, but in the case of the 'Royal Oak' and some other vessels, a layer of wood was interposed between the iron and the copper, and he could state the galvanic action had now been perfectly prevented. The inspection of ships on the Mediterranean station showed that the iron plates, insulated from copper by only a single layer of wood, remained perfect. He entreated those who had the success of this invention at heart to make experiments on a large scale, such as would satisfy the Government. He believed the Portsmouth experiments were valuable, though he knew they were not conclusive to some persons who saw them. The inertia which was charged against the Admiralty in this matter was equally applicable to private shipowners, for he was not aware of this system having been adopted by them any more than by the Government.

"Mr. YOUNG remarked that it had been found that the wood sheathing on the iron plates was an insufficient insulation. This had been shown in the French and Spanish vessels. The plan might answer if the ships were not exposed to heavy seas; but by these and other violent shocks contact between the iron and copper was often produced, and galvanic action was set up.

"Mr. MACKIE, in reply upon the discussion, said he was glad to have had the pleasure of listening to the remarks of Mr. Reed. That gentleman, he was sure, knew enough of him personally to be quite aware that if he used strong language in reference to the proceedings of Government, it was not out of personal animosity, or a desire to attack the Government or their officials, but simply because one who attempted to act upon the inertia always existing in Government departments, must express himself strongly, or he would have no hope of being listened to. With regard to the question of the cost of sheathing with zinc, it was stated in the paper that it would probably be one third that of copper. The copper required to be replaced on wooden ships every three or four years, while zinc would last, at a minimum, from five to seven years, and might be made to last from twelve to fourteen years, according to the thickness of it. With regard to the question of the expansion of zinc, he believed the difference in the amount of expansion and contraction between the zinc and iron would be very small in temperatures only ranging from 60° to 70°, or 80°, and would not be greater than would be relieved by a slight buckling of the zinc plate. He had not been able to go fully into all Mr. Daft's ideas with regard to the jointing of iron plates, but he had no disposition to measure his own experience in that matter with that of a gentleman like Mr. Reed. He did not gather, however, that Mr. Reed considered Mr. Daft's joint to be weaker than the butt joint. On the question of putting the copper sheathing on iron vessels over wood planking as an insulating material, he accepted Mr. Reed's statement of the result as perfectly correct. Still, it must be borne in mind that water would percolate wherever there was a crack, and so long as connection was made by the water between two opposing elements, so long he thought there was danger of corrosion by galvanic action.

"Mr. Reed said he should be sorry it should be supposed that he had implied that the plan of placing the copper sheathing on wood, as an insulating material, was quite satisfactory. If the plan described in the paper were successful, it would be immeasurably superior.

"Mr. Mackie was glad to hear that remark from Mr. Reed. He agreed with that gentleman that it was essential this system should be tried on a larger scale than it had been; and that this might be done was one great reason for his bringing the subject before this meeting. With regard to the putting a wooden layer to receive the copper sheathing, there was this further objection to it, that, whatever quantity of wood was put on the outside of the hull, it practically increased the size of the vessel, and, to that extent, increased the amount of resistance; and for every square foot of such increase there was a loss of one nominal horse-power, With regard to the carrying out of experiments on a large scale. he would ask was the inventor of this plan bound to build a vessel at his own expense, send it to sea, and keep it there a sufficient time to afford a thoroughly satisfactory test of the merits of the system? Mr. Reed might possibly be right in saying that the experiments at Shoeburyness were worth nothing; but the experiments at Portsmouth were carried out under official authority, and he was going to say nearly officially spoilt. If this system had merit, let it be tried on a proper scale; if it had no merit, he (Mr. Mackie) would be amongst the first to give it up. By this system the sheathing could be applied to the hull of the ship direct. If it required any insulating material, however thin, it did not realise what was claimed for it. He might add that, if the Government took experiments in hand at all, the least they could do was to carry them through; because, if they did not, they put the inventor in an unfair position. He believed the system would have been tried in the mercantile navy ere this if the trial experiments had not been in Government hands; but that being the case, people naturally waited the result of the Government trials. He, therefore, said, let the inventor try an experiment according to his own plans. Let him have some small iron vessel, even a condemned one, and let it be sheathed on his system. If, then, it was found wanting, let it be given up.

"The Chairman said, as to the importance of the subject treated in the paper, there could be no doubt. It was a national question to overcome the difficulties which still attached to the use of iron vessels. Iron had been so completely proved to be the better material in naval construction that the Government had largely adopted it; and yet there was one defect attaching to it, viz. that iron ships would foul very quickly. The means hitherto adopted were clearly insufficient as a remedy for the evil. The poisonous compounds spoken of he thought might be fairly dismissed from their minds as being playthings in connection with a very serious subject. Copper sheathing appeared very inapplicable, for when in contact with iron it invariably had the effect of corroding it, because the salt water would percolate between the two metals; and, moreover, the copper sheathing itself would fail in its purpose from the want of exfoliation of the surface. With regard to the insulation of the two metals by the interposition of a wooden layer, he agreed with Mr. Reed that the iron would be effectually protected so long as no metallic contact took place. The moisture between the two metals would not be sufficient to set up galvanic action, the battery would be in the condition of an 'open' battery, not a 'closed' one. There was, however, great difficulty in maintaining perfect separation, because wire, even of $\frac{1}{16}$th inch gauge, was sufficient to transmit a considerable current and produce a great amount of mischief upon the iron, and it was hardly to be supposed that the two enormous surfaces could be long kept perfectly separated without metallic connection being formed between them. What surprised him, somewhat, on hearing this paper was the very slow rate of exfoliation of the zinc. He had himself made experiments upon the action of the salt water upon zinc in contact with iron, and he found the zinc acquired weight up to about three months, but after that period a sensible diminution in weight took place. The author of the paper stated that the amount of the oxidation of the zinc was not more than $1\frac{3}{4}$ oz. or 2 oz., even if the exfoliation was made more active by an increased galvanic action. It would be interesting to ascertain whether there was any increased exfoliation when the ship was in motion. No doubt there would be some increase, but experiment would determine the amount. No doubt, chemically, zinc sheathing would protect the bottom of the vessel entirely, for even if a sheet of the metal were displaced there would still be the influence of the zinc in contact with the iron. So far, then, the invention appeared to him to be an exceedingly promising one, and one which he thought should certainly be tried seriously by the Admiralty. With regard to the observations of Mr. Reed, he thought he had stated the case very fairly, and he believed personally he would be disposed to afford the invention every trial it required; but, if the experiment at Portsmouth was to be taken as evidence of the anxiety of the Admiralty to inquire into the merits of new inventions, he thought in this case an injury had been done to the inventor. There was nothing, he thought, more destructive to the interests of an inventor than an imperfect trial.

"Mr. Reed thought it due to the Admiralty to say that the experiment was not initiated by them. They merely gave permission to Mr. Daft to put down some plates prepared on his system, but they were in no way pledged to go on with the experiments. At the same time, having gone to the extent they did, it might have been desirable that they should have continued the experiments further. He merely wished to say that the Admiralty did not initiate the experiments and then suddenly drop them. (Vide p. 124; also p. 186 in Appendix.)

"The Chairman said that altered the case in some respects; but he maintained that even the sanctioning of experiments implied, he thought, a continuation of them; those who were practically acquainted with the difficulties appertaining to the introduction of inventions would appreciate more than official personages could possibly do the great hindrance caused by incomplete experiments to the progress of an invention. If the intervention of the Government were entirely refused, the inventor was free to act as he pleased; but from the moment he placed his invention in the hands of the Government he was practically shut out from the public until a verdict upon it had been pronounced. He thought the Government might spend a few thousands a year very well in making really serious experiments upon questions of this nature. Even if such an invention as this were tried upon a merchant ship it would be no convincing proof to the Government of its merit. The Government must make its own experiments to determine its value. With regard to the mechanical mode of joining the plates, he thought it sufficient for this invention if it was admitted that there was no inconvenience thus caused. He did not think any great weight was to be attached to the question of the buckling of the plates; if the back-strap was carefully put on, there would be no fear of fracture unless, as mentioned by Mr. Reed, the back-strap had the fibre in the wrong direction. He thought Mr. Mackie had brought the whole subject very ably and fairly before them, and he was sure they could do no less than give him their thanks for having done so.

The vote of thanks was then passed.

The author learns that since this paper was read by Mr. Mackie he has carried out laboratory experiments to meet the electrical objections raised by Mr. Siemens, and finds that, after completely immersing in salt water three batteries, respectively consisting of a plate of iron insulated by wood from a plate of zinc, of iron insulated from iron, and iron insulated from copper, he has obtained three distinct grades of chemical action—the fluid in the bath of the zinc and iron elements being the least affected, the action of the salt water *per se* being considerable on the iron plates, whilst ochre was freely deposited in the bath of the copper and iron elements.

Mr. Mackie's experiments are not yet published, as he considers they should be repeated with the greatest possible care, to avoid the possibility of erroneous theoretical explanations of the action which takes place, and which the author believes he regards as probably of an electrolytic nature. His object has been to show that totally submerged elements are not in the condition of partially submerged elements, in which he regards the cushion of air at the open ends as an insulator of the plates, across which a metallic wire is a necessary conducting bridge for the electricity.

## FOULING.

The 'Times' of May 6th, 1867, states, in the "Naval and Military Intelligence," that "Her Majesty's iron steam store ship 'Supply' has been absent from Woolwich over six months, *considerably beyond her usual time,* which is accounted for by the *foul state of her bottom.* In order to remedy the defect she was *'hove over,'* and scraped by the *mechanical means at hand at Ascension.*"

In reference to the clean state in which the bottom of the "Great Eastern" was reported to have been by the 'Times' (as shown at page 79 of this work), when examined on the gridiron at Liverpool, in the beginning of the present year, Mr. Robert Murray, of Southampton, states, in a letter to 'Engineering' of May 17th, 1867, that "the *whole* bottom was *thickly encrusted* over with *shellfish* to a depth varying from *five inches to nine inches,* the weight of which was estimated at from 250 *to* 300 *tons*" *!!* So much for the efficiency of "anti-fouling" compositions.

It will be remembered that on the late occasion of the failure of the engines of the iron-clad ship "Minotaur," the 'Standard' was the first to announce the circumstance; but the 'Times' gave the statement a flat contradiction, affirming that the engines "on both days worked admirably," but at a later date admitted that there had been a breakdown, thus stultifying its former statement!

## IMPROVED CONSTRUCTION.

The 'Standard,' of May 23rd, 1867, in an article on "Naval Designs," which describes the features of a movement initiated by the First Lord of the Admiralty, requesting the most eminent shipbuilders to submit designs for iron-clad men-of-war to the Admiralty, states that "zincing the bottom of the ship will be entertained."

It is gratifying to learn from this that steps will now be taken to preserve the iron hulls of our ships from corrosion and fouling, by the employment of zinc as a sheathing, in place of copper or yellow metal, or the use of paints or compositions.

Of its success there can be no doubt, and it is hoped that the plan of construction invented and patented by Mr. Daft, for obtaining the advantages gained by abolishing "butts" and using the zinc sheathing, will be carried out in its integrity, so as to enable a full and fair trial to be made.

The article concludes with the remark that "we cannot but believe that the country will welcome every sincere effort made to secure the best plans for our national defences, ashore or afloat, and will rejoice to see a determination displayed not to permit prejudices, official or civilian, to interfere with the attainment of the most effective results."

The remark was made by Dr. Robison, that "an experiment does not establish a general proposition, and never can do more than prove a particular fact," but in the case of the experimental plates which have been described in this work it has been denied by some that even the particular fact they were arranged to illustrate has been proved!

In reply to Dr. Robison's remarks, there can be no doubt that, as the late Mr. Charles Wye Williams has observed, "The *proving a fact* is a decided step in actual progress, and enables us to draw inferences and illustrations, which, leading to other facts, bring us to absolute demonstration."

It is to be regretted that in some instances even the *proof of a fact* is not always admitted, and that this very circumstance of its being proved should act as a difficulty. As to trying to prove a a fact, there are, it may be remarked, *two* ways of going to work—one so that it *shall* succeed, the other so that it shall *not*; and it sometimes unfortunately happens that preference is given to the *latter* mode instead of the former.

There can be no reason why experiments should not be tried; in fact, they may be generally considered necessary, but it is most important that all should be fairly carried out, and honestly taken in hand, if it be really desired to arrive at correct results, or obtain any benefit from them.

It may be here remarked, that persons will be found to object to the cost of constructing and sheathing an iron ship on this plan because it would be more expensive *at the outset* than smearing, plastering, painting, or glueing; but such persons do not object to the continued evil of docking, loss of time in this operation, and the liability to fouling and corrosion perpetuated by the old system, and fail to appreciate the advantages of uniform speed and cleanliness, and safety from corrosion, which accrue for some three or four years or more if desired, by the use of this new system of "Dafting," and forget, as has been shown at page 136, that the entire cost may be almost saved in the *first* year.

Again, it is confidently objected by those who do not understand the matter that, if zinc sheathing is to be used, the existing ships of iron cannot be benefited thereby, as they allege a ship *must be specially constructed for its application.* A reference to page 131 will be a sufficient reply to this incorrect assertion; and although it is admitted, and is evident, that it does not make so good and workmanlike a job as if the ship were "Dafted" or specially built for the purpose, still a moment's reflection will show to any thinking practical man that the advantages and benefits ensured by its employment, as well as the fact that *none of them* are gained by *any* mode yet proposed or tried, would render this point of little moment; and even if it did require a little more care of the ship to keep her off the ground, or clear of docks, wharves, barges, lighters, &c., to prevent stripping the sheathing, still this little trouble would be amply repaid by the advantages secured by its adoption.

It is not often that objections are raised to building a single or double wooden ship over an iron hull, to carry the copper or yellow metal, nor are the great trouble, expense, and waste of time incurred thereby considered of any moment; yet zinc, which does not require any trouble, expense, or precautions of a similar kind, is evidently not thought of sufficient importance to receive any attention. Possibly its freedom from requiring such precautions may be considered an objection.

The "Dafting" system embodies three particular features:—First, a novel and superior mode of constructing iron ships; the second, obtaining flush and stronger hulls, on which, if any one is foolish enough to prefer it, they may nail copper or yellow-metal sheathing; and the third, the employment of sheets of metallic zinc as a protective from fouling and a preservative from corrosion for the hulls of iron ships. Consequently to give the system a fair trial, all these three points should be treated *as a whole.*

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